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MEASUREMENTS AND PREDICTIONS OF FLYOVER AND STATIC NOISE OF A TF30 AFTERBURNING TURBOFAN ENGINE

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INTRODUCTION

The effects of forward velocity on the noise produced by jet engines is an important factor in determining the environmental impact of aircraft noise. The characteristics of noise produced at static (ground) conditions are well documented for nonafterburning turbofan and turbojet engines. The static noise characteristics of afterburning engines are not so well known. The flyover noise characteristics of nonafterburning turbofan and turbojet engines have been the subject of several recent studies (refs. 1 and 2). However, the flyover noise characteristics of afterburning jet engines are not well documented. For supersonic transport aircraft powered by afterburning engines, the effects of forward velocity on noise must be known to provide an accurate assessment of such aircrafts' environmental acceptability. There is some evidence that internally generated noise, which is almost completely dominated by jet mixing noise at static conditions, becomes an important factor when forward velocity is considered (ref. 3).

Therefore, the NASA Dryden Flight Research Center conducted a series of tests to measure the noise characteristics of the TF30 afterburning turbofan engine. This engine was installed in an F-111 airplane and was involved in tests of an integrated propulsion control system (IPCS). The IPCS provided full-authority digital control of the left engine of the F-111 airplane. This provided a capability to repeatably vary some engine parameters, such as exhaust velocity profile, that cannot normally be controlled in flyover noise tests.

Flyover tests were conducted at a Mach number of approximately 0.4, a typical climbout speed for a supersonic aircraft, for a range of power settings. Static noise tests were conducted at similar engine conditions for comparison with the flyover data. A survey was made of exhaust temperatures and velocities for the various test conditions. Some preliminary results of all these tests are presented in reference 4. This paper presents more information about the tests, tabulations of the test results, and limited analysis. In addition, the noise measurements are compared with the results of current prediction methods. Sufficient data are presented to allow the reader to perform a more detailed analysis of the results.

SYMBOLS AND ABBREVIATIONS

Units are given in the International System of Units (SI) and parenthetically in U.S. Customary Units. Most of the measurements were made in Customary Units and converted to SI Units.

A	area, m^2 (ft^2)
D	diameter of exhaust exit, m (ft)
f	frequency, Hz
IPCS	integrated propulsion control system
K_I	constant (ref. 3)
M	Mach number
NPR	nozzle pressure ratio, p_{t_8}/p_{amb}
OASPL	overall sound pressure level, dB, ref. 2×10^{-5} Pa (2.9×10^{-9} lb/in^2)
OBCF	octave band center frequency, Hz
PNL	perceived noise level, dB, ref. 2×10^{-5} Pa (2.9×10^{-9} lb/in^2)
p	pressure, kN/m^2 (lb/in^2)
R	range from microphone to nozzle exit plane, m (ft)
R′	range from microphone to predominant noise source, m (ft)
SLD	sideline distance, m (ft)
SPL	sound pressure level, dB, ref. 2×10^{-5} Pa (2.9×10^{-9} lb/in^2)
T	temperature, K (°R)

V	velocity, m/sec (ft/sec)
W	mass flow, kg/sec (lb/sec)
x	distance downstream of nozzle, m (ft)
α	angle of attack, deg
γ	ratio of specific heats
θ	angle from inlet axis, referenced to nozzle exit plane, deg (figs. 9 and 12)
θ'	angle from inlet axis, referenced to predominant noise source, deg (see appendix)

Subscripts:

a	airflow
amb	ambient conditions
c	core portion of engine
corr	corrected
d	fan duct portion of engine
eff	effective
f	fuel flow
g	gas flow
i	ideal
ind	indicated
j	jet
m	main burner
t	total
0	free stream

3, 4, 6, 7, 8 engine stations (fig. 2), as follows:

3 compressor discharge

4 turbine inlet

6 afterburner inlet

7 primary nozzle exit

8 location at which exhaust is fully expanded to ambient pressure

DESCRIPTION OF TEST EQUIPMENT

F-111 Airplane

The F-111 airplane (fig. 1) is a two-place twin-engine supersonic fighter with variable-sweep wings. It is approximately 23 meters (76 feet) long and has a maximum weight in excess of 400,000 newtons (90,000 pounds). It is powered by two TF30 engines installed side by side in the aft fuselage. The inlets are located under the wing glove.

TF30 Engine

The TF30 engine (fig. 2) is a low bypass ratio (≈ 1) afterburning turbofan engine. It is equipped with a three-stage fan, a six-stage low pressure compressor, and a seven-stage high pressure compressor. The main combustor consists of eight burners of the can-annular type. A single-stage turbine drives the high pressure compressor, and a three-stage turbine drives the fan and low pressure compressor. The fan and core streams merge at the entrance to the afterburner, which is divided into five zones to allow the smooth modulation of thrust. As shown in figure 3, zone 1 is in the core stream near the fan duct-core boundary. Zones 2, 3, and 4 are located in the fan duct stream, and zone 5 is in the center of the core stream. Figure 4 shows the normal fuel flow to each zone as a function of throttle position for a typical test at static conditions. Military power (throttle angle of 68°) is the maximum nonafterburning power setting. As throttle angle increases, fuel flows sequentially to afterburning zones 1, 2, 3, 4, and 5. Since zones 2, 3, and 4 are in the fan stream, the maximum zone 4 power setting causes most of the afterburner fuel to be distributed to the fan flow. The maximum zone 5 power setting results in an approximately uniform distribution of fuel in the fan and core streams. During afterburning operation, the gas generator is reset at a higher performance level. This resetting causes the main engine fuel flow, the turbine discharge pressure and temperature, and the fan and core airflows to increase above the military power levels.

The flameholders for the afterburner are shown in figure 5. The annular flameholders are for core zones 1 and 5, and the radial flameholders are for the fan duct zones (zones 2, 3, and 4). A variable-area convergent nozzle is used to control the pressure level in the afterburner during afterburning operation. A blow-in-door ejector nozzle is installed downstream of the primary nozzle. The blow-in doors were open to the mechanical limits of the configuration for all data reported herein; at high power settings, the primary nozzle restricted the blow-in-door opening, as shown in figure 3. The blow-in-door mass flow at static conditions is approximately 45.4 kilograms per second (100 pounds per second) at military power and decreases to 16 kilograms per second (35 pounds per second) at maximum afterburning power.

Integrated Propulsion Control System

The IPCS had full-authority control of the left propulsion system on the F-111 airplane. The system equipment consisted of electronic fuel controls, new pressure and temperature sensors, an electrohydraulic inlet control, a digital computer and interface unit, and a computer monitor unit in the cockpit. The IPCS had full-authority control of the fuel flow to the main engine, of the primary nozzle area, and of the fuel flow to all five afterburner zones. The control modes for these parameters could be varied by using the cockpit computer monitor unit. The IPCS incorporated an in-flight thrust computation capability and a detector for afterburner instability (called rumble) in the range from 40 hertz to 60 hertz. A more complete description of the IPCS is given in reference 5.

INSTRUMENTATION

F-111 Airplane

Approximately 220 parameters were recorded on board the airplane during the ground and flight tests. The parameters included most engine control input and output parameters and some internally calculated parameters. Airplane speed, altitude, angle of attack, fuel quantity, and pressures and temperatures at various locations in the engine were also recorded. The data were recorded on an onboard tape recorder and were also telemetered to a ground station for real time display and monitoring.

Exhaust Survey Rake

An exhaust survey rake designed for pollution studies (ref. 6) was provided by the NASA Lewis Research Center for use in the engine tests. The rake was mounted in a large frame and could be translated horizontally and vertically. Figure 6 shows the survey rake positioned behind the F-111 airplane. Because of protruding airplane parts, the probes had to be placed about 20 centimeters (7.9 inches) downstream of the secondary nozzle. In the full inboard position, the rake was in the exhaust for high engine power settings. In the full outboard position, the rake was entirely outside the exhaust.

The rake was equipped with four total temperature probes and one total pressure probe (fig. 7). Three of the four temperature probes incorporated iridium/iridium-rhodium (Ir/Ir-Rh) thermocouples, while the center probe was a shielded platinum/platinum-rhodium (Pt/Pt-Rh) thermocouple probe. The top and bottom Ir/Ir-Rh probes were unshielded; the other Ir/Ir-Rh probe had a platinum shield. The shielded probes were not expected to survive the entire test, but were installed to get radiation correction data for the unshielded probes, as discussed in Data Reduction and Analysis.

The pressure, temperature, and position measurements from the exhaust survey rake were recorded by the airplane data acquisition system.

Acoustic Instrumentation

Several acoustic surveys were made, each with a different microphone arrangement. The data acquisition system shown in figure 8 was used for each test. Each channel consisted of a condenser microphone with cathode follower, a power supply, and a line-drive amplifier. Line-drive amplifiers were used at each location. The signal from the line-drive amplifier was routed through shielded two-conductor cable to a mobile acoustic van, where the data were recorded on a 14-track wide-band FM recorder. Oral comments describing each test and a broadcast time code were also recorded.

Before and after each day's test, an acoustic calibration was applied to each microphone channel. The resulting signal was recorded for use in the data reduction process. In addition, a pink noise calibration was recorded for each microphone channel to verify flat frequency response over the analysis frequency range.

Atmospheric temperature, wind, and humidity were measured above the acoustic van (10 meters (33 feet) above the ground) for all of the acoustic tests. Atmospheric pressure was measured by the aircraft data acquisition system.

Static Noise Survey Instrumentation

Static noise surveys were conducted on the Edwards Air Force Base static thrust measurement facility, which is a large, flat, circular concrete area 66 meters (216 feet) in diameter with a concrete taxiway extending from one end (fig. 9). The concrete is bordered by a strip of asphalt approximately 10 meters (33 feet) wide. The soil beyond the pavement is sandy and sparsely vegetated. The nearest buildings are approximately 1000 meters (3300 feet) away.

Static noise measurements were made at distances of 10 meters (33 feet) and 33 meters (110 feet) to the side of the exhaust centerline, as shown in figure 9. The exact angular locations of the microphones varied from one test to another; the choice of location was based on previous results. For the later tests, microphones were eliminated from the forward quadrant, and microphones were added in the rear quadrant at angles between 120° and 140°. All measurements were made over concrete. The microphones were mounted inverted, with the diaphragm about 1.3 centimeters (0.5 inch) above the concrete. This arrangement was used to minimize uncertainties due to ground reflection (ref. 1). Each microphone was inside a cylindrical windscreen that was 7.6 centimeters (1.9 inches) in diameter, 12.0 centimeters (3.0 inches) high, and covered by 0.01-centimeter (0.005-inch) thread at 44 threads per centimeter (112 threads per inch). A row of microphones is shown in figure 10.

Flyover Noise Survey Instrumentation

For the flyover noise tests, the microphone array shown in figure 11 was used. Inverted microphones with windscreens identical to those used in the static tests were placed 15.2 meters (50.0 feet) apart at 11 locations along the centerline of the flightpath. The microphone array was on a dry lakebed, a smooth, hardpacked, sandy clay surface capable of supporting large airplanes.

Radar Tracking

For the flyover noise tests, the NASA FPS-16 precision tracking radar was used to indicate the airplane's position with respect to the microphones. The airplane was equipped with a radar transponder to aid in the tracking. The radar data were recorded on magnetic tape along with a time code for use in the data reduction. The radar data were also displayed in real time to verify the flight track and altitude.

Engine Thrust Instrumentation

The thrust of the TF30 engine at various power settings was measured on the Edwards Air Force Base thrust-measuring facility. Thrust and static noise measurements were made simultaneously. The accuracy of the thrust measurement was believed to be ±1320 newtons (±300 pounds), or about 2 percent of a single engine's maximum thrust.

Since the airplane could not be located on the thrust facility for all of the static tests, sufficient instrumentation was installed in the engine to permit engine thrust to be calculated. The Pratt & Whitney gas generator method was used, and the calculation was performed in the IPCS computer as described in reference 5. Thrust was calculated for all the static noise tests, exhaust velocity tests, and flyover noise tests.

DATA REDUCTION AND ANALYSIS

Exhaust Velocity Survey Data

The exhaust velocity survey data were recorded in the airplane's data acquisition system. Temperature corrections and velocity were calculated in a data reduction program.

Lag in the temperature measurements was evaluated by traversing the exhaust in one direction and then returning in the other direction. The temperature lag was not considered significant for afterburning conditions, and was neglected in the data reduction.

The total temperatures recorded by unshielded Ir/Ir-Rh thermocouples were subject to radiation errors at high temperatures. The following equation from reference 7 was used to correct these errors (The equation is in SI Units):

$$T_{corr} = \frac{2.845}{\sqrt{Mp_t}} \left(\frac{T_{ind}}{555.6}\right)^{3.82} \left[1 + \frac{4}{9}\left(\frac{T_{ind}}{555.6}\right)\right]$$

In U.S. Customary Units the equation is:

$$T_{corr} = \frac{1.976}{\sqrt{Mp_t}} \left(\frac{T_{ind}}{1000}\right)^{3.82} \left[1 + \frac{4}{9}\left(\frac{T_{ind}}{1000}\right)\right]$$

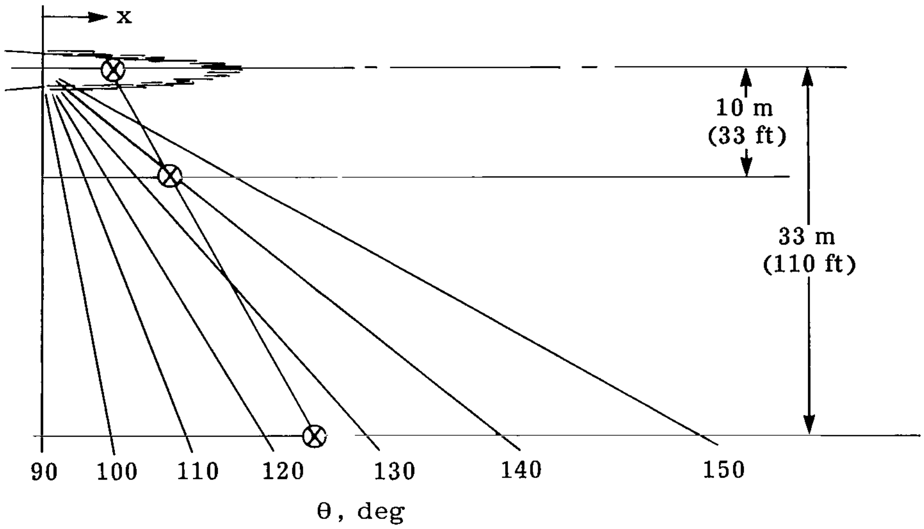
The correction typically amounts to approximately 10 K (18° R) at an indicated temperature of 1100 K (1980° R) and approximately 114 K (205° R) at an indicated temperature of 2200 K (3960° R). Although the shielded thermocouple probes did not survive the severe environment in the exhaust, the data they provided at high temperatures before failing substantiated the correction used.

Static pressure was not measured in the exhaust velocity survey and was assumed to equal the ambient pressure measured at the airplane nose boom. The exhaust nozzle pressure ratio (NPR) indicated slightly supersonic flow at some power settings, and the assumption of ambient static pressure caused small errors in velocity for these conditions. The ambient static pressure measurements and total pressure measurements were used along with the fuel-to-air ratio and the ratio of specific heats calculated from temperature to calculate the exhaust Mach number. Thus, an iterative procedure was necessary to arrive at a final exhaust Mach number. The final exhaust Mach number was multiplied by the local speed of sound to arrive at the exhaust velocity.

Static Noise Survey Data

Data recorded from the static noise survey were processed with a computer-controlled real time analyzer that met FAR Part 36 (ref. 8) specifications. The data were subsequently scaled, and frequency corrections were made. Atmospheric attenuation corrections based on the simplified method of reference 8 were made. Standard day (ref. 8) values of overall sound pressure level (OASPL) and perceived noise level (PNL) were calculated in addition to one-third octave band sound pressure levels. No attempt was made to correct the data to free field conditions. Data were averaged over time intervals ranging from 10 seconds to 45 seconds. The estimated accuracy of the static noise data is ±0.5 decibel.

The locations of predominant noise sources in the exhaust were identified by using data from the two sideline microphone arrays by using the method described in reference 9. The one-third octave band sound pressure levels (SPL's) were plotted as a function of θ, and maximum values were obtained for the 10-meter (33-foot) sideline array and the 33-meter (110-foot) sideline array. These maximum values were plotted, and the location of the noise source along the exhaust centerline was identified graphically, as shown in the sketch below.



The free field noise predictions in references 3 and 10 were compared with the measured data. The difference between free field predictions and measurements made with ground plane microphones amounts to 6.0 decibels. For this reason, 6.0 decibels were added to the predicted noise values for all of the comparisons. An additional correction was necessary for the prediction of static jet mixing noise because the angle between the microphone and the jet axis, θ, was measured with respect to the nozzle exit, whereas the source of jet mixing noise was downstream of the nozzle (see sketch). The correction described in the appendix was made to account for this discrepancy.

Radar Tracking Data

The radar tracking data from the flyovers were processed by using a digital computer program. The program first screened the data for wild points, which were eliminated. The data were then smoothed with a Kalman filter with coefficients optimized for that flyover track. Once a smoothed set of data was obtained, axis transformations were performed to relate airplane location to microphone location. A 13-meter (42.6-foot) shift was also incorporated to account for the distance between the radar transponder and the exhaust exit. The exhaust angle was calculated from aircraft flightpath, angle of attack, and microphone location as shown in figure 12.

Flyover Noise Survey Data

Acoustic data from the 11 centerline microphones were processed by the Boeing Commercial Airplane Company to produce an ensemble average for each flyover. This technique permitted a short averaging time (0.1 second) to be used while retaining reasonable statistical validity. To produce the ensemble average, the analysis time for each successive microphone was delayed by the time required for the aircraft to traverse the 15.2 meters (50.0 feet) between microphones. The time histories for each microphone were inspected for adequate signal-to-noise ratio, noise spikes, and consistency with the other microphone time histories, and questionable data were thrown out. The remaining time histories were then logarithmically averaged for each flyover. The time histories were then corrected to a 152-meter (500-foot) flyover on a standard day. The data were again inspected for adequate signal-to-noise ratio, and some of the high frequency data at very small and very large values of θ (long propagation distances) were found to be in error due to large atmospheric attenuation corrections. In a few other cases, 60-cycle noise was present for small values of θ. Data that were incorrect for these reasons were eliminated prior to the calculation of OASPL values. The remaining data were corrected to the appropriate exhaust angle, but no attempt was made to correct the data to free field conditions. The estimated accuracy of the flyover noise was ±1 decibel.

The prediction methods described in references 3, 11, 12, and 13 were used to calculate jet mixing, internal, and shock noise for the flyover data. Corrections were made to these predictions to account for atmospheric absorption and the use of ground microphones. The correction described in the appendix was applied to the jet mixing noise component of the flyover noise prediction to account for the downstream source of the jet mixing noise.

Engine Performance Data

It would have been preferable to measure thrust, exhaust velocity, and noise simultaneously and for each test. However, simultaneous measurements were impractical. Therefore, thrust and velocity profiles had to be calculated for some of the static tests and all of the flyover tests. (Thrust and velocity profiles were also calculated when measurements were available, for comparison purposes.) The only data available for all tests were engine and airplane data, which included measurements of temperature, pressure, fuel flow, airflow, and nozzle area. From these measurements, the exhaust pressure ratio, fuel flow distribution, and airflow during different tests could be compared, and exhaust velocity, temperature, and thrust could be calculated.

To calculate these parameters, the primary nozzle mass flow was calculated from engine airflow and fuel flow. Then the primary nozzle total pressure was calculated from the measured turbine discharge pressure and pressure loss through the afterburner, which was a function of mass flow and afterburner fuel flow. The nozzle pressure ratio was the primary nozzle total pressure divided by the ambient pressure measured at the airplane nose boom. At this point, the temperatures from the exhaust velocity survey were assumed to be equal to those for the static noise and flyover noise surveys with the same power setting. This assumption was justified because the IPCS maintained a constant fuel-to-air ratio, which should have resulted in a nearly constant temperature.

With the calculated pressure and temperature, the exhaust flow was expanded isentropically to ambient pressure to obtain an estimated ideal exhaust velocity. For the flyover tests, a relative exhaust velocity was obtained by subtracting airplane velocity from exhaust velocity. Mass flow through the blow-in doors was not considered as part of the exhaust mass flow.

TEST PROCEDURE

Three series of tests were conducted: the exhaust velocity survey, the static noise survey, and the flyover noise survey. Thrust measurements were made during two of the static noise tests. Several power settings were used during each test series; these are listed in table 1, which also indicates the tables and figures in which the corresponding data are presented. The lowest power setting was military (maximum nonafterburning). The maximum zone 4 power setting distributed most of the afterburner fuel to the fan duct stream and therefore produced a nonuniform temperature profile. The maximum zone 5 power setting resulted in an approximately uniform distribution of fuel to the core and fan duct streams.

Additional exhaust conditions were obtained by using the IPCS to modify the normal control modes. One such power setting, termed adjusted zone 4, was obtained by reducing the zone 1 fuel flow by 80 percent while at maximum zone 4 fuel flow for zones 2, 3, and 4. This caused almost all of the afterburner fuel to be burned in the fan stream. Another power setting, termed reduced zone 5, was obtained by uniformly reducing the fuel flow to all five zones with the IPCS while at the maximum zone 5 power setting. This produced a uniform but lower distribution of fuel in the afterburner.

During the ground tests, the engine was operated at its maximum rated nozzle pressure ratio, which produced an exhaust exit Mach number of approximately 1.0. During the flyover tests, operation of the engine at maximum rated NPR resulted in an exhaust exit Mach number of approximately 1.12 because of the ram recovery of the inlet. In order to provide a comparison with the ground test data, the IPCS was used to downtrim the engine for some of the flyover noise tests to match the ground test NPR. This caused the exhaust Mach number to be reduced to approximately 1.0.

Thrust Measurements

In two of the static noise tests, noise and thrust measurements were made simultaneously to compare the noise produced by nonuniform thrust profiles with the noise produced by uniform thrust profiles.

Another reason for making the thrust measurements was to compare the measurements with the thrust calculations made by the IPCS computer. Agreement was excellent, with the calculated thrust falling within the error of the thrust stand measurement (ref. 5).

Exhaust Velocity Survey

The exhaust velocity survey was conducted to determine exhaust velocity and temperature profiles for the tested range of power settings. The traversing rake was set so that the upper Ir/Ir-Rh thermocouple would pass through the center of the exhaust as horizontal traverses were made. The total pressure probe was 2.5 centimeters (1 inch) below this temperature probe. During the first tests, lag data and radiation correction data were obtained at selected power conditions. After these data were acquired, single traverses were made through the center of the exhaust for all power settings to acquire basic temperature and velocity data. Finally, a survey 15 centimeters (6 inches) above the exhaust centerline was made and a vertical survey near the edge of the jet was made to determine the velocity gradients for the maximum zone 4 (nonuniform profile) power setting. Table 2 shows the engine parameters for the exhaust survey.

Static Noise Survey

In total, four static noise tests were conducted. During each test, the noise was measured for a range of power settings. During three of these tests, the noise was measured first with an array of microphones on a line approximately 10 meters (33 feet) from the exhaust axis. Later, the microphones were moved to a line approximately 33 meters (110 feet) from the exhaust axis. Because of temperature differences, and hence changes in engine conditions, the 10-meter and 33-meter sideline data could not be compared directly. In the fourth static noise test, simultaneous measurements were made at the 10-meter (33-foot) and 33-meter (110-foot) sidelines (fig. 9). Engine performance data for the fourth static test are presented in table 3. The noise caused by power settings that produced uniform exhaust velocity profiles were compared with the noise caused by power settings of equal thrust that produced nonuniform exhaust velocity profiles.

During all of the static noise tests, winds were less than 3 meters per second (10 feet per second). During the fourth test, winds were calm, and relative humidity was 30 percent.

Flyover Noise Survey

A flyover noise survey was conducted to determine the effects of forward velocity on noise and to obtain data for comparison with the static noise data. Table 4 summarizes the flyover test conditions and engine performance data. The flyovers were made at altitudes between 152 meters (500 feet) and 168 meters (550 feet). The target Mach number over the microphone array was 0.40 (approximately 130 meters per second (426 feet per second)). The right engine was kept at idle power during the flyovers and did not contribute any significant noise. (Previous flyovers were made by an F-111 airplane in the clean configuration (landing gear and flaps retracted) with both engines at the idle power setting, and the combined engine and airframe noise had OASPL values at least 10 decibels below the lowest measured noise levels reported herein.)

During the flyovers at the afterburning power settings, thrust was sufficient to cause the airplane to accelerate significantly. For these cases, the flyovers were initiated below the target airspeed, and an attempt was made to pass over the microphone array at the target airspeed. The actual variation in speed, shown in table 4, was from Mach 0.40 (133 meters per second (437 feet per second)) to Mach 0.44 (147 meters per second (482 feet per second)). During the flyover between $\theta = 20^\circ$ and 160°, which took about 7 seconds, the maximum speed change was 9 meters per second (30 feet per second), which is not believed to have affected the data significantly.

The flyovers were conducted in the morning, while temperatures gradually increased from 283 K (509° R) to 289 K (521° R). Relative humidity decreased from 47 percent to 28 percent during the tests. Winds ranged from calm to 1 meter per second (3 feet per second) for all the tests. Tests 12 to 15 were flown at the full rated nozzle pressure ratio while tests 16 to 26 were flown with the NPR down-trimmed to match static conditions. Tests 22 to 26 were repetitions of tests 16 to 20.

RESULTS AND DISCUSSION

Exhaust Velocity Survey

Results of the exhaust velocity survey are presented in figure 13 in terms of total pressure, total temperature, and velocity as a function of distance left and right from the exhaust center as seen in cross section.

Total pressure profiles. - The total pressure profiles determined from horizontal traverses of the various exhaust streams are shown in figure 13(a). The military power profile is uniform in the center of the exhaust and falls off gradually at the edges, where blow-in-door air mixes with it. For the afterburning power settings, the exhaust radius increases because the nozzle area is larger. The total pressure in the center of the exhaust is higher for the maximum zone 4 and adjusted zone 4 conditions because of the afterburner reset; however, when zone 5 is burning, the pressure loss due to afterburning heat addition results in a lower total pressure. For the maximum zone 5 power setting, the primary nozzle is fully open.

Total temperature profiles. - The total temperature profiles are shown in figure 13(b). The profile for military power is well rounded as a result of mixing between the hot core stream and the cool fan stream in the afterburner and nozzle. The temperature in the center of the exhaust is somewhat lower than the core discharge temperature of 878 K (1580° R) (table 2). For the afterburning power settings, large temperature gradients occur. The maximum zone 5 temperature profile peaks at 2200 K (3960° R) and exhibits a dip in the center of 300 K (450° R). The reduced zone 5 temperature profile also dips near the center of the exhaust. The maximum zone 4 profile exhibits temperatures of 2000 K (3600° R) at the edge of the jet and 1000 K (1800° R) in the center. The adjusted zone 4 profile is similar, with a center temperature of 920 K (1660° R), which is almost equal to the core discharge temperature (table 2).

Velocity profiles. - The velocity profiles are shown in figure 13(c). The military power peak velocity is about 530 meters per second (1740 feet per second). The maximum zone 5 peak velocity is 850 meters per second (2790 feet per second), while the reduced zone 5 peak velocity is 800 meters per second (2625 feet per second).

These values are slightly higher than the average ideal velocities that were calculated from the engine-measured parameters in table 2, primarily because the calculation assumed a uniform pressure and temperature profile. For the maximum zone 4 power setting, the peak velocity is 820 meters per second (2690 feet per second), while the velocity at the center is 610 meters per second (2000 feet per second). For the adjusted zone 4 conditions, the peak velocity is 800 meters per second (2625 feet per second) and the center velocity is 590 meters per second (1935 feet per second). No ideal velocity was calculated for these nonuniform profiles.

In general, the exhaust profiles were symmetrical, except that the temperatures on the inboard side were somewhat lower than on the outboard edge during afterburning. The thrust of the exhaust was calculated by integrating the measured temperatures, pressures, and velocity data and was in reasonably good agreement with the thrust calculated by the IPCS computer for all power settings.

Static Noise Survey

The static noise data obtained during the fourth test, in which simultaneous measurements were made at the 10-meter (33-foot) and 33-meter (110-foot) sidelines, are presented in tables 5 and 6, respectively. Engine performance data for these tests are given in table 3.

Ten-meter (33-foot) sideline noise. - A summary of the OASPL data at the 10-meter (33-foot) sideline is shown in figure 14, along with a set of data from one of the earlier static noise tests, in which a larger number of microphones were used on the 10-meter (33-foot) sideline.

The two sets of data agree reasonably well, with differences of approximately 1 decibel. For military power (fig. 14(a)), the peak OASPL occurs at $\theta = 143^\circ$, and for the afterburning power settings (figs. 14(b) to 14(e)), the peak OASPL occurs at $\theta = 140^\circ$, based on the more extensive data from the earlier test.

Thirty-three-meter (110-foot) sideline noise. - The static noise data from the 33-meter (110-foot) sideline microphones are presented in figure 15. These data were obtained at the same time as the 10-meter (33-foot) sideline data presented in figure 14. The peak OASPL occurs at $\theta = 140^\circ$ at military power and at approximately 130° at the afterburning power settings.

The measured noise was compared with predictions obtained by using the method described in reference 3. Reference 3 provides a method for the calculation of internal noise (also called core noise), which is produced by the combustion process and flow inside the engine. Internal noise is a function of the main burner mass flow, pressure, and temperature increase. The empirical equation in reference 3 incorporates a constant, K_I, which was assumed to be 52 for nonafterburning and afterburning conditions. Reference 10 gives a good description of the mechanism of internal noise generation.

Reference 3 also provides a method for the calculation of jet mixing noise, which is a function of exhaust velocity, temperature, density, and exhaust area. The jet mixing noise and internal noise are logarithmically added to provide a prediction of the total exhaust noise. The comparison is shown in figure 16. Data for the military power setting are shown in figure 16(a). The predicted jet mixing noise is, as expected, substantially higher than the predicted internal noise. The predicted total noise agrees well with the total measured noise. The predicted peak OASPL is about 1 decibel less than measured, but it occurs at nearly the same angle.

For maximum afterburning conditions (fig. 16(b)), the predicted total noise agrees well with the measured total noise for angles less than 140°. For angles greater than 140°, the predicted level is well above that measured. This discrepancy was probably caused by the lack of very high temperature-low density exhaust data during the development of the prediction method.

The predicted and measured noise for the reduced zone 5 (test 8) and maximum zone 4 power settings are compared in figure 16(c). The thrust during the tests was equal, even though the velocity profiles were different, so both tests can be compared with the same prediction. The reduced zone 5 power setting data are similar to the maximum zone 5 data in figure 16(b). The maximum zone 4 power setting data are 1 decibel to 2 decibels below the equal thrust reduced zone 5 data, probably because of the inverted velocity profile of the maximum zone 4 power setting, as discussed in reference 4.

Adjusted zone 4 power setting noise data are compared with data for an equal thrust reduced zone 5 power setting in figure 16(d). The results are similar to those in figure 16(c), with the nonuniform inverted profile jet 1 decibel to 2 decibels quieter than the uniform jet.

Static noise spectra at the 33-meter (110-foot) sideline. - One-third octave band sound spectra from the 33-meter (110-foot) sideline microphones are shown in figure 17 for military power and in figure 18 for maximum afterburning power. Also shown are predicted spectra from reference 11. In general, the data agree reasonably well with the predictions. Some deviations from a smooth spectrum shape are apparent for military power at $\theta = 140°$ and 150° (figs. 17(e) and 17(f)) and for maximum afterburning power at $\theta = 120°$, 130°, and 140° (figs. 18(c), 18(d), and 18(e)). These deviations were also observed in the 10-meter (33-foot) sideline noise data, and may be caused by reflections off the afterbody fairing between the engines (fig. 5).

Sound spectra from the 33-meter (110-foot) sideline for the maximum zone 4 and the equal thrust reduced zone 5 (test 8) power settings are shown in figure 19. Data are shown for $\theta = 40°$, 90°, 120°, 125°, 130°, and 140°, where the OASPL data (fig. 16(c)) showed that there were differences between the two sets of data. The maximum zone 4 spectra are generally 2 decibels to 3 decibels lower than the reduced zone 5 spectra in the 100-hertz to 1000-hertz range for θ from 120° to 130°. The maximum zone 4 data exhibit a peak at 80 hertz.

This peak was found for all $\theta = 120°$ data where zone 4 fuel flow was at its maximum value; see the 10-meter (33-foot) sideline data (tables 5(b), 5(d), and 5(e)) and the 33-meter (110-foot) sideline data (table 6(e)). The 80-hertz tone was found to originate inside the nozzle, and is believed to be the result of a stable combustion oscillation in the afterburner. The 80-hertz tone does not occur in the reduced zone 5 power setting data, in which the zone 4 fuel flow is less than maximum.

At $\theta = 140^\circ$ (fig. 19(f)), there is essentially no difference between the maximum zone 4 and reduced zone 5 power setting data at low frequencies, but the zone 4 data are lower at high frequencies.

Noise source locations. - The noise data from the two sideline microphone arrays were used to find the locations of the predominant sources of the various noise frequencies, as discussed in the Data Reduction and Analysis section. The results are shown in figure 20 for military power and three afterburning power settings. Also shown are data from reference 9 for a hot jet model with an exit diameter of 15.24 centimeters (6 inches). The data show, as expected, that the high frequencies are generated near the nozzle exit, while the low frequencies originate much farther (approximately 10 nozzle diameters) downstream. The TF30 data show the same trends as the hot jet data, but there are also some significant differences. The military power noise sources appear to be approximately twice as far downstream as for the model jet and afterburning data. This may be because, in the military power case, the velocity gradient through the exhaust is much less severe than in the afterburning case (see the velocity profiles, fig. 13(c)); the mixing is therefore slower. There is also considerable spread in the results at fD/V values above 1.0. The reasons for these differences are not known, but they may be related to the geometry of the blow-in-door ejector nozzle, differences between the velocity profiles of the various power settings, or deficiencies in the source location technique.

Flyover Noise Survey

The flyover noise data acquired are presented in table 7. Engine and airplane information for the flyover tests is included in table 4. The engine was operated at rated NPR for tests 12 to 15, which resulted in flow at the exit that was supersonic, with Mach numbers of 1.12 to 1.15. The rest of the flyovers were flown with the engine downtrimmed to match static conditions, and the exit flow Mach number was sonic, at a Mach number of approximately 1.0.

Nonafterburning results. - The measured flyover noise for a test at military power (test 12) is shown in figure 21. The noise level increases rapidly for $\theta = 20^\circ$ to 40°, remains approximately constant to $\theta = 90^\circ$, increases to a peak at $\theta = 140^\circ$, and then falls off rapidly. Also shown are the predicted jet mixing and internal noise from reference 3 and the predicted shock noise from reference 12. The shock noise is dominant for θ less than 50°. The jet mixing noise is reduced by the effects of relative velocity and does not become dominant until $\theta = 105^\circ$. The internal noise is increased in the forward quadrant by the effects of convective amplification, and is dominant for $\theta = 50^\circ$ to 105°. The measured data agree very well with the sum of the three predicted noise sources.

Measured sound spectra at $\theta = 40^\circ$, 90°, and 130° are shown in figure 22. The predicted shock noise spectra from references 12 and 13 are also shown. For $\theta = 40^\circ$, a spectral peak occurs at 800 hertz, which agrees well with the predicted shock noise spectrum. The shock noise peak was evident for $\theta = 20°$ to $70°$, and its appearance in the measured sound spectra in the forward quadrant is consistent with the results in reference 9. The measured spectrum at $\theta = 90°$ does not show a shock noise peak, but is flat and may be affected by shock noise. The 130° spectrum appears to be a pure jet mixing spectrum, and it compares favorably with the shape of the static noise spectrum (fig. 17(d)).

Data for the two military power flyovers with the NPR reduced to match the static conditions (tests 16 and 22) are shown in figure 23. Agreement between the two flyovers is very good, with differences of less than 1 decibel. Data from test 16 are slightly above the data from test 22, which is consistent with the slightly higher exhaust velocity for test 16.

Agreement with the total noise predicted by reference 3 is excellent. The predicted internal noise is higher than the predicted jet mixing noise; the predictions appear to be borne out by the excellent agreement of the flyover data. No shock noise is expected, since the exhaust is not supersonic. It is extremely unlikely that this close agreement could result from incorrect but compensating predictions of jet mixing and internal noise, particularly since the jet mixing noise prediction is well understood for nonafterburning exhausts.

Measured sound spectra for the military power sonic exhaust data (tests 16 and 22) are shown in figure 24 for $\theta = 40°$, $90°$, and $130°$. The agreement between the spectra for the two flyovers is good. The spectra in figure 22 for the military power supersonic exhaust are repeated for comparison. The differences between the two conditions at $\theta = 40°$ are due to shock noise. The close agreement at frequencies below 500 hertz is probably because of the similar internal noise for the flyovers. At $\theta = 90°$ and $\theta = 130°$, the supersonic exhaust spectra are higher at all frequencies than the two sonic exhaust spectra because of the increased internal noise and the contribution of jet mixing noise.

For all the military power flyovers, both supersonic and sonic, internal noise is a major contributor to the flyover noise, and it is accurately predicted by the reference 3 method. However, the TF30 engine operating in the military power (nonafterburning) mode may not be typical of other nonafterburning turbojet or turbofan engines because of the presence of afterburner spraybars, flameholders, the afterburner liner, and the variable-geometry exhaust nozzle in the flow path.

Afterburning results. - Results of the afterburning power setting flyovers are shown in figure 25 for supersonic exhaust conditions and in figure 26 for sonic exhaust conditions. For the supersonic exhaust conditions, the predictions in reference 3 were used for internal and jet mixing noise, and the prediction in reference 12 was used for shock noise. The shock noise is dominant for θ less than 60°; the measured noise is above the predicted noise for $\theta = 40°$ to $130°$ and below the prediction for θ greater than 140°. The prediction exhibits a deficiency at values of θ greater than 140°, as it did for afterburning static noise.

Results are very similar for the sonic exhaust afterburning results in figure 26. The predicted jet mixing noise peak agrees with the measured peak, but it occurs at a farther aft angle.

In the forward quadrant and for θ up to 120°, the data indicate a large contribution of internal noise. However, the internal noise prediction of reference 3 makes no attempt to account for the afterburning process, and therefore would not be expected to predict the correct value of internal noise.

The sound spectrum for a test with supersonic exhaust (test 15) is compared to spectra for tests with sonic exhausts (tests 19 and 25) in figure 27. A shock noise peak is evident at θ = 40° for the supersonic exhaust (fig. 27(a)), as it was for the nonafterburning supersonic exhaust (fig. 24(a)). At θ = 130°, the spectrum for the supersonic exhaust (test 15) agrees well with the Doppler-shifted predicted jet mixing spectrum from reference 11.

Inferred afterburning internal noise. - The data in figures 25 and 26 were used to infer the internal noise of the afterburning flyovers. The sonic exhaust data in figure 26 should be free of shock noise, and, therefore, the difference between the measured noise and the predicted jet mixing noise in the forward quadrant is assumed to be internal noise. The resulting internal noise is shown in figure 28(a) for five flyovers. The prediction from reference 3 is also shown. The afterburning internal noise appears to be 4 decibels above the prediction at θ = 40° and 8 decibels above the prediction at θ = 90°. To arrive at the inferred internal noise for the supersonic exhaust (fig. 28(b)), the predicted shock noise and jet mixing noise were subtracted from the measured supersonic exhaust data in figure 25. Again, the inferred internal noise is higher than the prediction, by 3 decibels at θ = 40° and by 6 decibels at θ = 90°.

If the inferred internal noise is, as is indicated here, due to the afterburning combustion process and the associated flow phenomena, internal noise should be considered in future engine designs that incorporate afterburning or duct burning. It may be particularly important to consider internal noise if jet mixing noise is to be reduced by the use of the coannular exhaust nozzle configuration or a mechanical noise suppressor. In the case of the TF30 engine, this internal noise is not evident during static tests (fig. 16), and only becomes apparent with forward velocity.

Nonuniform exhaust velocity profile noise. - Noise from the maximum zone 4 and adjusted zone 4 power settings that produced inverted exhaust velocity profiles was measured in the flyover noise survey and compared with the noise produced by uniform exhaust velocity profile reduced zone 5 flyovers. The calculated thrust for tests 24 and 25 was almost identical; however, the airplane velocities differed by 9 meters per second (31 feet per second). Therefore, the jet mixing noise prediction method in reference 3 was used to correct the data for test 25 for values of θ where jet mixing noise was dominant (greater then 100°) to the same flyover velocity as for test 24. The results are shown in figure 29(a). The noise level with the inverted exhaust velocity profile is approximately 1 decibel quieter than with the equal thrust uniform exhaust velocity profile at values of θ where jet mixing noise should be dominant.

A similar comparison is shown in figure 29(b) for adjusted zone 4 and equal thrust reduced zone 5 tests. In this case, no velocity corrections were necessary. Again, at values of θ greater than 110°, the noise level with the inverted exhaust velocity profiles is lower than with the uniform exhaust velocity profile by approximately 1 decibel. The noise level in test 26 is lower than in test 20, because of the slightly higher ambient temperature.

Figure 29(c) shows the same type of comparison, except that the exhaust was supersonic. Again, at the peak OASPL levels, the noise level with the inverted exhaust velocity profile is slightly lower than with the uniform exhaust velocity profile.

The forward quadrant noise levels in figure 29 show no consistent difference between the uniform and inverted exhaust velocity profiles, because internal noise is dominant.

Differences between the uniform and inverted exhaust velocity profile sound spectra are shown in figure 30 for $\theta = 130°$. The differences tend to be spread across the frequency band for the three comparisons.

CONCLUSIONS

Flyover and static (ground) noise measurements were made on a TF30 afterburning turbofan engine in an F-111 airplane. A survey was also conducted to measure the exhaust temperature and velocity profiles for a range of power settings. Comparisons were made between predicted and measured shock noise, internal noise, and jet mixing noise. The following conclusions were drawn:

1. The noise produced at static conditions was dominated by jet mixing noise, and was adequately predicted.

2. The noise produced during flyovers exhibited large contributions from internally generated noise in the forward arc. For flyovers with the engine at nonafterburning power, the jet mixing noise, shock noise, and internal noise were accurately predicted. During afterburning flyovers, however, additional internal noise believed to be due to the afterburning process was evident; its level was as much as 8 decibels above the nonafterburning internal noise. No prediction is available for afterburning internal noise.

3. Power settings that produced exhausts with inverted velocity profiles appeared to be slightly less noisy than power settings of equal thrust that produced uniform exhaust velocity profiles both in flight and in static testing.

4. Designs of future afterburning or duct-burning engines should take into consideration the effects of internal noise, which may not be evident from static testing.

Dryden Flight Research Center
National Aeronautics and Space Administration
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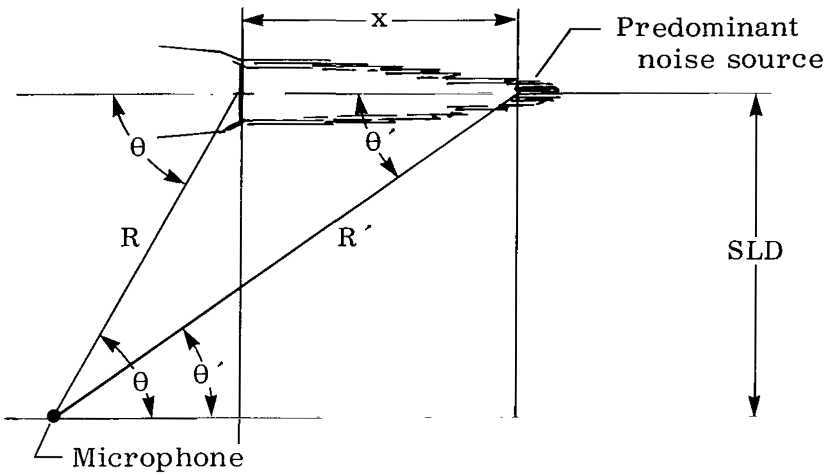
APPENDIX—SOURCE LOCATION CORRECTIONS

A correction had to be made to the static and flyover jet mixing noise predictions because the sideline and flyover noise measurements were made with the jet angle, θ, defined with respect to the nozzle exit plane. In reality, however, the source of jet mixing noise was downstream of the nozzle exit plane. The angles and terms used for the correction were defined as shown below:



The angular correction to the data is as follows:

$$\theta - \theta' = \theta - \tan^{-1}\left(\frac{1}{\frac{1}{\tan\theta} + \frac{x}{SLD}}\right)$$

The correction to OASPL was made as follows:

$$\Delta OASPL = 20 \log \left(\frac{R'}{R}\right) = 20 \log \left(\frac{\sin \theta'}{\sin \theta}\right)$$

Figure 31 shows the resulting corrections to the jet mixing noise predictions for a source distance, x, of 9.1 meters (30 feet) for 33-meter (110-foot) sideline and 152-meter (500-foot) flyovers.

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TABLE 1.—TEST POWER SETTINGS AND TABLE AND FIGURE NUMBERS FOR TEST DATA

(a) Exhaust velocity survey

Test number	Power setting	Table number for engine performance data	Figure number for data
1	Military	2	13
2	Maximum zone 4		
3	Reduced zone 5		
4	Adjusted zone 4		
5	Maximum zone 5		

(b) Static noise survey

Test number	Power setting	Table number for engine performance data	Sideline distance, m (ft)			
			10 (33)	33 (110)	10 (33)	33 (110)
			Table numbers for noise data		Figure numbers for data	
6	Military	3	5	6	14	15, 16, 17
7	Maximum zone 4					15, 16, 19
8	Reduced zone 5					15, 16, 19
9	Maximum zone 5					15, 16, 18
10	Adjusted zone 4					15, 16
11	Reduced zone 5					16

(c) Flyover noise survey

Test number	Power setting	Table number for engine performance data	Table number for noise data	Figure numbers for data
12	Military	4	7	21, 22
13	Maximum zone 5			25(a)
14	Maximum zone 4			29(c), 30(c)
15	Reduced zone 5			25(b), 29(c), 30(c)
16	[a]Military			23, 24
17	[a]Maximum zone 5			26(a)
18	[a]Maximum zone 4			----------
19	[a]Reduced zone 5			26(b), 27
20	[a]Adjusted zone 4			29(b), 30(b)
21	[a]Reduced zone 5			26(c), 30(b)
22	[a]Military			23, 24
23	[a]Maximum zone 5			26(a)
24	[a]Maximum zone 4			29(a), 30(a)
25	[a]Reduced zone 5			26(b), 27, 29(a), 30(a)
26	[a]Adjusted zone 4			29(b)

[a]Engine downtrimmed to match flyover NPR to static NPR.

TABLE 2.—ENGINE PERFORMANCE DATA FOR EXHAUST VELOCITY SURVEY

[p_0 = 93.1 kN/m^2 (13.50 lb/in^2)]

Test number	T_{amb}, K (°R)	V_0, m/sec (ft/sec)	Main combustor parameters				
			W_{a_c}, kg/sec (lb/sec)	T_{t_3}, K (°R)	p_3, kN/m^2 (lb/in^2)	W_{f_m}, kg/sec (lb/sec)	T_{t_4}, K (°R)
1	281 (506)	0 (0)	46.7 (103)	716 (1289)	1448 (210)	0.916 (2.02)	1376 (2477)
2	279 (503)	0 (0)	47.6 (105)	725 (1305)	1517 (220)	0.985 (2.17)	1411 (2540)
3	279 (502)	0 (0)	48.1 (106)	726 (1307)	1517 (220)	0.985 (2.17)	1408 (2535)
4	279 (502)	0 (0)	47.6 (105)	727 (1308)	1523 (221)	0.981 (2.16)	1405 (2530)
5	279 (503)	0 (0)	48.1 (106)	728 (1310)	1531 (222)	0.985 (2.17)	1411 (2540)

Test number	Afterburner core zone parameters			Afterburner fan duct zone parameters		
	$p_{t_{6_c}}$, kN/m^2 (lb/in^2)	$T_{t_{6_c}}$, K (°R)	W_{f_c}, kg/sec (lb/sec)	W_{a_d}, kg/sec (lb/sec)	$T_{t_{6_d}}$, K (°R)	W_{f_d}, kg/sec (lb/sec)
1	185 (26.8)	878 (1580)	0 (0)	47.2 (104)	390 (703)	0 (0)
2	199 (28.9)	911 (1640)	0.762 (1.68)	46.3 (102)	388 (699)	2.47 (5.44)
3	199 (28.9)	911 (1640)	1.43 (3.16)	45.8 (101)	388 (698)	1.75 (3.85)
4	200 (29.0)	910 (1638)	0.15 (0.33)	46.3 (102)	388 (698)	2.44 (5.37)
5	198 (28.7)	913 (1643)	2.02 (4.45)	45.8 (101)	388 (699)	2.45 (5.40)

Test number	Primary nozzle parameters						Fully expanded exhaust conditions		
	γ	T_{t_7}, K (°R)	p_{t_7}, kN/m^2 (lb/in^2)	A_7, m^2 (ft^2)	W_{g_7}, kg/sec (lb/sec)	M_7	A_8, m^2 (ft^2)	V_{8_i}, m/sec (ft/sec)	$V_{8_{eff}}$ from rake, m/sec (ft/sec)
1	1.37	778 (1400)	180 (26.1)	0.353 (3.80)	94.8 (209.0)	1.03	0.324 (3.49)	523 (1716)	530 (1740)
2	1.28	Nonuniform	183 (26.5)	0.573 (6.17)	98.1 (216.3)	1.065	0.558 (6.01)	--------	--------
3	1.28	1722 (3100)	179 (26.0)	0.575 (6.19)	98.1 (216.2)	1.045	0.560 (6.03)	778 (2553)	800 (2625)
4	1.29	Nonuniform	184 (26.7)	0.539 (5.80)	97.5 (214.9)	1.070	0.523 (5.63)	--------	--------
5	1.25	2000 (3700)	174 (25.2)	0.660 (7.10)	99.4 (219.0)	1.030	0.653 (7.03)	833 (2735)	850 (2790)

TABLE 3.—ENGINE PERFORMANCE DATA FOR STATIC NOISE SURVEY

[p_0 = 93.1 kN/m^2 (13.50 lb/in^2); humidity: 28 percent; wind: calm]

Test number	T_{amb}, K (°R)	V_0, m/sec (ft/sec)	Main combustor parameters				
			W_{a_c}, kg/sec (lb/sec)	T_{t_3}, K (°R)	p_3, kN/m^2 (lb/in^2)	W_{f_m}, kg/sec (lb/sec)	T_{t_4}, K (°R)
6	295 (531)	0 (0)	43.2 (95.3)	728 (1310)	1372 (199)	0.878 (1.935)	1400 (2520)
7	295 (531)	0 (0)	45.1 (99.3)	733 (1320)	1392 (202)	0.932 (2.054)	1422 (2560)
8	295 (531)	0 (0)	45.1 (99.5)	733 (1320)	1400 (203)	0.921 (2.03)	1422 (2560)
9	295 (531)	0 (0)	45.4 (100.0)	733 (1320)	1400 (203)	0.934 (2.059)	1422 (2560)
10	295 (531)	0 (0)	45.1 (99.5)	733 (1320)	1400 (203)	0.934 (2.058)	1422 (2560)
11	295 (531)	0 (0)	45.1 (99.5)	733 (1320)	1392 (202)	0.921 (2.03)	1422 (2560)

Test number	Afterburner core zone parameters			Afterburner fan duct zone parameters		
	$P_{t_{6_c}}$, kN/m^2 (lb/in^2)	$T_{t_{6_c}}$, K (°R)	W_{f_c}, kg/sec (lb/sec)	W_{a_d}, kg/sec (lb/sec)	$T_{t_{6_d}}$, K (°R)	W_{f_d}, kg/sec (lb/sec)
6	182 (26.4)	894 (1610)	0 (0)	47.6 (105.0)	403 (725)	0 (0)
7	192 (27.8)	922 (1660)	0.720 (1.587)	45.9 (101.1)	404 (727)	2.39 (5.27)
8	190 (27.5)	922 (1660)	1.307 (2.88)	45.8 (101.0)	404 (727)	1.63 (3.59)
9	192 (27.8)	922 (1660)	1.906 (4.20)	46.1 (101.6)	404 (727)	2.46 (5.42)
10	192 (27.9)	922 (1660)	0.145 (0.32)	47.1 (103.9)	404 (727)	2.52 (5.55)
11	190 (27.6)	922 (1660)	1.642 (3.62)	46.7 (103.0)	404 (727)	1.48 (3.27)

Test number	Primary nozzle parameters						Fully expanded exhaust conditions		
	γ	T_{t_7}, K (°R)	P_{t_7}, kN/m^2 (lb/in^2)	A_7, m^2 (ft^2)	W_{g_7}, kg/sec (lb/sec)	M_7	A_8, m^2 (ft^2)	V_{8_i}, m/sec (ft/sec)	$V_{8_{eff}}$, m/sec (ft/sec)
6	1.34	722 (1300)	174 (25.3)	0.353 (3.80)	91.7 (202.2)	1.00	0.324 (3.49)	487 (1597)	495 (1625)
7	1.28	Nonuniform	169 (24.6)	0.580 (6.24)	94.6 (208.5)	0.995	0.565 (6.08)	Nonuniform	----------
8	1.28	1722 (3100)	168 (24.3)	0.577 (6.21)	94.8 (209.0)	0.985	0.562 (6.05)	735 (2410)	756 (2480)
9	1.27	2055 (3700)	162 (23.5)	0.655 (7.05)	98.0 (216.2)	0.960	0.647 (6.97)	783 (2568)	800 (2623)
10	1.29	Nonuniform	172 (25.0)	0.553 (5.95)	95.9 (211.4)	1.00	0.536 (5.77)	Nonuniform	----------
11	1.29	1555 (2800)	170 (24.7)	0.551 (5.93)	95.9 (211.4)	0.99	0.534 (5.75)	702 (2305)	724 (2375)

TABLE 4.—ENGINE PERFORMANCE DATA FOR FLYOVER NOISE SURVEY
[Humidity: 28 to 47 percent; wind: calm to 1 m/sec (3 ft/sec)]

Test number	T_{amb}, K (°R)	V_0, m/sec (ft/sec)	Main combustor parameters					
			W_{a_c}, kg/sec (lb/sec)	T_{t_3}, K (°R)	P_3, kN/m^2 (lb/in^2)	W_{f_m}, kg/sec (lb/sec)	T_{t_4}, K (°R)	
12	283 (509)	133 (437)	52 (115)	736 (1325)	1641 (238)	0.98 (2.17)	1377 (2478)	
13	283 (510)	143 (469)	54 (120)	739 (1330)	1703 (247)	1.08 (2.38)	1405 (2530)	
14	283 (510)	143 (468)	54 (119)	739 (1330)	1703 (247)	1.08 (2.37)	1402 (2524)	
15	285 (513)	147 (482)	54 (119)	739 (1330)	1717 (249)	1.08 (2.38)	1396 (2514)	
16	286 (514)	136 (446)	45 (100)	674 (1213)	1331 (193)	0.70 (1.54)	1205 (2170)	
17	286 (515)	139 (455)	46 (101)	679 (1222)	1358 (197)	0.74 (1.64)	1247 (2245)	
18	287 (516)	135 (443)	46 (102)	682 (1227)	1372 (199)	0.73 (1.69)	1248 (2246)	
19	287 (517)	146 (478)	47 (103)	685 (1233)	1386 (201)	0.77 (1.70)	1257 (2263)	
20	288 (518)	143 (470)	46 (102)	685 (1233)	1386 (201)	0.77 (1.69)	1257 (2263)	
21	288 (519)	142 (466)	47 (103)	684 (1231)	1379 (200)	0.76 (1.68)	1254 (2257)	
22	289 (520)	135 (442)	44 (98)	672 (1210)	1296 (188)	0.68 (1.50)	1203 (2165)	
23	289 (520)	138 (453)	45 (100)	681 (1226)	1351 (196)	0.74 (1.62)	1245 (2241)	
24	289 (520)	135 (443)	47 (103)	681 (1226)	1344 (195)	0.75 (1.66)	1245 (2242)	
25	289 (520)	144 (474)	47 (103)	681 (1226)	1358 (197)	0.74 (1.64)	1241 (2234)	
26	289 (521)	140 (459)	47 (103)	682 (1228)	1351 (196)	0.74 (1.64)	1244 (2240)	

Test number	Afterburner core zone parameters			Afterburner fan duct zone parameters		
	$P_{t_{6_c}}$, kN/m^2 (lb/in^2)	$T_{t_{6_c}}$, K (°R)	W_{f_c}, kg/sec (lb/sec)	W_{a_d}, kg/sec (lb/sec)	$T_{t_{6_d}}$, K (°R)	W_{f_d}, kg/sec (lb/sec)
12	208.2 (30.2)	869 (1565)	----------	55 (122)	402 (724)	----------
13	227.5 (33.0)	913 (1643)	2.31 (5.09)	54 (118)	403 (725)	2.87 (6.33)
14	227.5 (33.0)	911 (1640)	0.87 (1.91)	54 (118)	403 (726)	2.85 (6.29)
15	229.6 (33.3)	911 (1640)	1.58 (3.48)	54 (118)	403 (726)	2.20 (4.86)
16	182.7 (26.5)	772 (1390)	----------	53 (117)	396 (712)	----------
17	191.7 (27.8)	807 (1453)	1.41 (3.12)	52 (115)	396 (713)	2.80 (6.18)
18	192.4 (27.9)	811 (1460)	0.72 (1.60)	52 (115)	397 (714)	2.79 (6.15)
19	194.4 (28.2)	809 (1457)	1.47 (3.24)	53 (116)	397 (715)	2.22 (4.90)
20	194.4 (28.2)	813 (1464)	0.16 (0.36)	53 (117)	397 (715)	2.83 (6.25)
21	193.1 (28.0)	809 (1457)	1.27 (2.81)	53 (116)	398 (716)	1.86 (4.10)
22	179.3 (26.0)	768 (1382)	----------	53 (117)	398 (716)	----------
23	190.3 (27.6)	809 (1457)	1.43 (3.15)	52 (115)	398 (717)	2.79 (6.16)
24	189.6 (27.5)	807 (1453)	0.72 (1.59)	51 (113)	398 (717)	2.76 (6.08)
25	191.7 (27.8)	807 (1453)	1.47 (3.25)	52 (114)	399 (718)	2.21 (4.87)
26	190.3 (27.6)	806 (1450)	0.16 (0.36)	52 (114)	399 (718)	2.78 (6.12)

Test number	Primary nozzle parameters						Fully expanded exhaust conditions		
	γ	T_{t_7}, K (°R)	P_{t_7}, kN/m^2 (lb/in^2)	A_7, m^2 (ft^2)	W_{g_7}, kg/sec (lb/sec)	M_7	A_8, m^2 (ft^2)	V_{8_i}, m/sec (ft/sec)	$V_{8_{eff}}$, m/sec (ft/sec)
12	1.38	778 (1400)	198.6 (28.8)	0.351 (3.78)	108.5 (239.2)	1.11	0.335 (3.61)	570 (1869)	578 (1897)
13	1.27	2000 (3700)	193.1 (28.0)	0.660 (7.10)	114.2 (251.8)	1.12	0.656 (7.06)	896 (2941)	913 (2996)
14	1.285	Nonuniform	200.0 (29.0)	0.580 (6.24)	112.3 (247.6)	1.14	0.570 (6.14)	----------	----------
15	1.285	1722 (3100)	202.0 (29.3)	0.580 (6.24)	112.4 (247.7)	1.15	0.570 (6.14)	857 (2812)	879 (2884)
16	1.38	667 (1200)	175.1 (25.4)	0.350 (3.77)	99.2 (218.5)	1.01	0.327 (3.52)	475 (1560)	484 (1588)
17	1.27	2000 (3600)	161.3 (23.4)	0.660 (7.10)	103.0 (226.9)	0.96	0.656 (7.06)	769 (2523)	769 (2523)
18	1.285	Nonuniform	166.9 (24.2)	0.620 (6.67)	102.7 (226.4)	0.99	0.613 (6.60)	----------	----------
19	1.285	1722 (3100)	167.5 (24.3)	0.620 (6.67)	103.8 (228.8)	1.00	0.613 (6.60)	745 (2446)	745 (2446)
20	1.30	Nonuniform	173.1 (25.1)	0.570 (6.14)	103.1 (227.3)	1.02	0.559 (6.02)	----------	----------
21	1.30	1555 (2800)	171.7 (24.9)	0.570 (6.14)	103.3 (227.6)	1.01	0.559 (6.02)	716 (2350)	746 (2350)
22	1.38	667 (1200)	171.7 (24.9)	0.351 (3.78)	98.2 (216.5)	1.00	0.328 (3.53)	470 (1542)	478 (1570)
23	1.27	2000 (3600)	160.0 (23.2)	0.660 (7.10)	102.5 (225.9)	0.96	0.656 (7.06)	769 (2523)	769 (2523)
24	1.285	Nonuniform	165.5 (24.0)	0.620 (6.67)	102.2 (225.3)	0.98	0.613 (6.60)	----------	----------
25	1.285	1722 (3100)	166.9 (24.2)	0.620 (6.67)	102.9 (226.8)	0.98	0.613 (6.60)	730 (2397)	730 (2397)
26	1.30	Nonuniform	168.9 (24.5)	0.570 (6.14)	102.1 (225.1)	1.00	0.559 (6.02)	----------	----------

TABLE 5.—TEN-METER (33-FOOT) SIDELINE STATIC NOISE DATA
[Ground microphone, standard day]

(a) Military

One-third OBCF, Hz	θ, deg				
	90	108	124	135	143
	SPL, dB				
50	101.9	104.0	106.2	109.3	113.3
63	107.9	109.0	111.2	114.9	119.4
80	106.8	109.3	112.1	116.1	120.3
100	110.0	112.6	114.7	118.8	122.9
125	111.2	113.9	116.6	120.6	124.9
160	113.5	115.9	119.1	121.9	126.5
200	114.1	116.7	119.2	123.0	128.6
250	116.9	117.3	119.9	123.3	129.2
315	116.9	118.3	119.9	123.3	127.4
400	115.9	118.0	120.0	123.4	126.7
500	115.4	117.2	119.9	122.9	125.4
630	116.3	118.3	120.3	122.7	124.4
800	115.2	118.0	120.3	121.9	122.7
1000	114.3	117.1	120.2	121.4	121.3
1250	113.9	116.7	119.4	120.5	119.8
1600	113.6	116.6	118.6	119.6	117.9
2000	113.4	115.9	117.8	117.8	116.1
2500	112.1	114.8	116.3	116.0	113.9
3150	112.2	113.6	115.1	114.0	111.7
4000	110.8	113.1	113.5	112.1	109.7
5000	110.6	112.3	111.9	110.5	107.8
6300	110.7	112.2	111.4	109.7	107.0
8000	109.1	109.5	108.7	106.9	105.0
10000	106.5	107.5	106.3	105.5	104.4
OASPL	127.1	129.2	131.2	133.7	136.8
PNL	138.4	140.4	141.9	142.7	143.8

(b) Maximum zone 4

One-third OBCF, Hz	θ, deg				
	90	108	124	135	143
	SPL, dB				
50	110.0	113.3	115.8	118.9	122.4
63	112.2	116.5	120.2	123.1	126.5
80	116.3	121.7	127.2	130.7	133.2
100	117.2	120.0	123.8	128.4	133.1
125	118.3	120.6	124.1	128.0	132.6
160	120.4	122.4	126.1	130.3	134.0
200	120.7	122.9	127.4	132.1	136.1
250	121.2	123.6	128.3	132.9	138.3
315	121.8	124.7	129.0	133.6	137.8
400	123.4	126.1	129.9	134.7	137.5
500	123.8	127.1	130.6	135.0	136.7
630	124.4	128.2	132.0	135.7	134.1
800	125.4	128.6	132.5	134.7	131.7
1000	125.7	129.6	132.6	132.9	130.0
1250	125.5	129.2	132.0	131.0	128.2
1600	125.2	128.7	131.0	130.0	126.2
2000	125.6	128.8	130.1	128.3	124.4
2500	124.5	128.0	128.0	126.1	122.7
3150	124.4	126.7	126.7	124.0	119.9
4000	122.2	125.6	124.9	122.0	117.9
5000	120.7	123.8	122.7	120.3	115.7
6300	119.9	123.1	122.0	119.2	114.7
8000	117.5	120.1	119.0	116.3	112.1
10000	114.7	118.1	116.3	114.8	109.9
OASPL	136.3	139.5	142.2	144.6	146.3
PNL	148.9	151.9	153.1	153.2	153.7

TABLE 5.— Continued

(c) Reduced zone 5 (test 8)

One-third OBCF, Hz	θ, deg				
	90	108	124	135	143
	SPL, dB				
50	110.6	112.9	115.2	118.8	123.3
63	113.3	115.4	117.8	122.5	127.2
80	114.3	117.5	120.7	126.0	130.9
100	117.5	120.4	123.4	128.5	133.2
125	119.3	121.2	124.4	129.8	134.0
160	119.5	121.4	125.0	131.8	135.7
200	120.3	123.1	126.9	133.7	138.6
250	121.6	124.2	127.7	134.4	140.5
315	122.1	124.8	128.9	134.9	139.7
400	123.0	126.1	129.4	135.7	140.7
500	123.4	126.7	129.3	135.8	138.7
630	123.9	127.5	130.5	135.6	137.3
800	124.6	128.1	130.6	134.9	135.0
1000	124.8	128.5	130.9	133.7	133.5
1250	124.3	127.9	130.3	132.0	131.7
1600	124.4	128.1	129.3	130.8	129.7
2000	124.7	128.1	128.4	128.9	128.0
2500	123.3	127.2	126.4	126.9	125.8
3150	123.2	125.5	125.0	124.8	123.4
4000	121.2	124.5	123.2	122.9	121.1
5000	119.9	122.7	121.0	121.3	118.9
6300	119.1	121.8	119.8	119.9	117.4
8000	116.5	118.7	116.7	116.8	114.5
10000	114.9	116.3	113.7	115.1	111.5
OASPL	135.6	138.8	140.8	145.3	148.6
PNL	148.0	151.1	151.6	153.8	156.0

(d) Maximum zone 5

One-third OBCF, Hz	θ, deg				
	90	108	124	135	143
	SPL, dB				
50	115.9	118.6	122.2	125.1	128.0
63	116.2	119.3	123.3	126.6	130.0
80	117.7	122.1	127.1	130.9	134.1
100	118.2	121.5	125.9	130.7	135.4
125	119.6	121.9	125.2	130.3	135.4
160	121.0	123.6	126.8	132.6	136.0
200	121.4	124.4	129.0	135.2	138.8
250	122.0	124.8	128.9	136.2	141.3
315	122.3	125.4	129.9	136.0	139.7
400	123.4	126.7	130.7	138.0	139.3
500	123.9	127.5	131.6	137.9	137.6
630	124.4	128.3	132.5	137.9	135.6
800	124.9	128.5	132.9	136.4	133.7
1000	124.8	128.9	133.5	134.8	132.0
1250	124.8	128.7	133.0	133.2	130.2
1600	124.7	128.5	132.1	132.0	128.3
2000	124.5	127.9	130.9	130.2	126.6
2500	123.2	126.9	128.9	128.2	124.4
3150	123.0	125.7	127.3	126.0	121.9
4000	121.0	124.8	125.5	124.1	119.7
5000	119.8	123.1	123.5	122.3	117.4
6300	119.1	122.4	122.7	121.2	116.1
8000	116.6	119.4	119.8	118.2	113.4
10000	113.5	117.3	117.3	116.6	111.0
OASPL	135.9	139.4	143.1	147.0	148.5
PNL	148.1	151.4	154.0	155.4	155.3

TABLE 5.—Concluded

(e) Adjusted zone 4

One-third OBCF, Hz	θ, deg				
	90	108	124	135	143
	SPL, dB				
50	110.8	113.2	116.1	119.3	122.6
63	113.6	116.4	119.4	123.2	127.0
80	117.1	122.7	127.1	131.1	133.9
100	116.9	119.8	123.1	127.9	131.8
125	118.1	119.8	122.7	127.6	131.7
160	119.5	121.6	124.1	128.7	132.7
200	120.3	123.3	126.6	130.9	135.2
250	120.9	123.8	126.9	131.1	136.8
315	121.8	124.7	127.9	131.7	136.0
400	122.9	126.0	128.7	132.9	137.0
500	123.7	126.8	129.5	133.4	135.8
630	124.4	127.9	130.5	133.8	134.4
800	125.2	128.7	131.4	133.4	131.8
1000	125.9	129.2	131.9	132.6	130.2
1250	125.3	128.6	131.0	130.8	128.4
1600	125.4	129.0	130.0	129.5	126.5
2000	126.1	129.2	129.2	127.9	124.8
2500	124.7	128.5	127.4	126.1	122.9
3150	124.5	126.6	126.3	124.0	120.6
4000	122.2	125.5	124.6	122.2	118.6
5000	121.1	124.0	122.8	120.7	116.5
6300	120.3	123.2	122.1	119.6	115.5
8000	117.9	120.4	119.2	115.9	112.9
10000	115.1	118.4	116.8	115.4	110.5
OASPL	136.3	139.5	141.3	143.4	145.6
PNL	149.0	152.1	152.4	152.6	153.0

(f) Reduced zone 5 (test 11)

One-third OBCF, Hz	θ, deg				
	90	108	124	135	143
	SPL, dB				
50	110.6	112.6	115.0	118.5	123.1
63	113.5	114.9	118.6	122.7	126.9
80	115.0	118.5	122.6	127.2	131.6
100	117.9	120.4	124.3	129.0	133.2
125	118.7	121.1	124.2	129.2	133.4
160	119.5	121.6	125.3	131.2	135.2
200	120.4	123.6	126.8	133.5	138.2
250	121.4	124.2	127.3	133.4	139.4
315	121.6	124.7	128.3	133.8	138.4
400	122.7	125.5	129.2	134.4	139.5
500	122.9	126.3	129.6	134.7	137.6
630	123.3	126.8	130.1	134.7	136.3
800	124.0	127.6	130.4	133.9	133.8
1000	124.2	127.6	130.4	132.8	132.1
1250	123.6	127.3	129.8	131.4	130.2
1600	123.8	127.7	129.2	130.1	128.3
2000	124.4	127.5	128.3	128.2	126.5
2500	122.8	126.3	126.4	126.2	124.4
3150	122.5	124.6	125.1	124.1	122.0
4000	120.5	123.6	123.3	122.2	119.6
5000	119.1	122.0	121.1	120.5	117.3
6300	118.3	120.9	120.1	119.0	115.9
8000	115.8	117.8	116.9	116.0	113.0
10000	113.4	115.4	113.9	114.4	110.1
OASPL	135.1	138.3	140.6	144.4	147.6
PNL	147.5	150.4	151.5	153.1	154.9

TABLE 6.—THIRTY-THREE METER (110-FOOT) SIDELINE STATIC NOISE DATA
[Ground microphone, standard day]

(a) Military power

One-third OBCF, Hz	θ, deg												
	30	40	50	70	90	100	110	115	120	125	130	140	150
	SPL, dB												
50	84.7	86.4	87.8	90.9	95.5	95.9	96.1	98.2	99.6	100.5	103.0	108.5	104.6
63	92.9	92.5	94.1	95.8	97.5	100.1	100.9	102.2	103.5	105.1	107.9	112.6	109.7
80	89.2	91.4	93.8	96.3	98.1	100.5	102.1	104.0	105.9	106.7	110.2	115.6	114.0
100	91.7	94.3	95.7	97.2	100.7	103.3	104.5	106.0	108.1	108.9	112.4	117.1	117.1
125	92.8	94.6	95.0	98.7	102.1	104.9	106.9	108.3	110.3	111.1	114.6	117.0	118.9
160	93.9	94.8	95.9	99.9	104.1	106.1	108.3	109.4	111.5	112.6	116.8	117.6	119.1
200	95.2	96.8	98.3	101.4	106.0	107.4	109.7	110.7	112.1	113.4	118.4	120.4	115.0
250	98.0	99.0	102.4	107.5	107.1	108.6	110.7	111.5	112.9	113.5	117.1	121.7	115.7
315	97.0	98.8	103.1	105.5	106.6	108.7	110.6	111.5	112.9	113.7	117.2	117.8	117.9
400	96.6	98.5	101.5	103.4	105.8	108.4	110.5	111.4	112.8	113.2	116.1	117.6	116.9
500	96.6	98.4	100.7	102.8	105.5	107.7	109.9	111.1	112.5	112.5	115.0	115.9	113.6
630	96.5	98.8	100.5	103.2	105.8	108.3	110.2	111.2	112.4	111.8	113.9	114.2	112.7
800	95.0	97.3	99.7	103.0	104.9	107.5	110.0	111.0	111.5	110.9	112.5	111.8	109.9
1000	93.8	96.1	98.8	102.6	104.4	107.0	109.1	110.3	111.3	110.2	111.4	109.9	107.7
1250	92.7	95.5	98.1	101.8	103.8	106.5	108.2	109.3	110.3	108.8	110.0	108.0	105.4
1600	91.8	94.5	97.5	101.7	103.4	105.9	107.4	108.3	109.5	107.4	108.3	105.9	103.2
2000	90.4	93.7	97.1	101.4	103.0	105.6	106.5	107.4	107.7	106.0	106.9	103.9	100.6
2500	89.0	93.3	97.0	101.1	102.3	104.6	105.4	106.2	105.0	104.5	104.9	101.5	97.5
3150	87.6	92.3	96.3	100.5	101.5	103.2	103.8	104.4	103.9	102.2	102.7	98.3	94.2
4000	87.4	91.6	95.5	100.7	101.0	102.7	103.1	103.1	103.3	100.6	100.8	96.0	91.1
5000	85.2	90.3	93.7	99.1	100.1	101.0	101.2	101.3	100.8	98.9	99.0	93.9	88.5
6300	84.0	88.0	92.0	98.3	99.1	100.8	100.8	100.5	100.5	98.2	97.9	92.2	87.8
8000	82.8	86.3	89.7	95.4	96.4	97.9	98.3	98.6	97.1	96.0	96.4	90.0	------
10000	------	85.3	87.8	92.0	95.1	95.2	95.4	95.7	95.2	93.4	93.8	88.8	------
OASPL	107.0	109.0	111.8	115.3	117.3	119.3	121.1	122.1	123.3	123.4	126.5	128.5	126.8
PNL	116.1	119.3	122.6	126.7	128.2	130.1	131.3	132.1	132.5	131.7	133.7	134.5	137.0

TABLE 6.—Continued

(b) Maximum zone 4

One-third OBCF, Hz	θ, deg												
	30	40	50	70	90	100	110	115	120	125	130	140	150
	SPL, dB												
50	94.7	97.1	96.8	100.5	104.8	107.2	108.2	111.2	113.3	115.2	116.0	120.8	118.3
63	98.4	98.8	98.7	102.6	107.7	109.3	111.0	114.0	115.4	118.6	120.0	124.0	119.8
80	99.2	100.4	100.3	104.2	108.3	112.2	116.2	118.7	121.3	123.8	125.1	127.4	120.7
100	99.6	101.2	101.2	104.5	108.8	111.6	114.0	116.3	118.8	121.8	124.4	128.7	122.3
125	100.2	101.5	101.5	105.6	110.0	112.2	114.7	116.4	118.5	120.8	122.6	128.0	123.3
160	100.0	102.0	101.9	106.7	111.0	113.6	116.3	118.6	121.2	123.2	124.3	124.9	123.3
200	100.6	102.2	103.1	106.9	112.1	114.4	117.7	120.0	122.4	124.9	127.2	124.2	121.5
250	100.8	102.6	103.4	107.9	112.7	115.1	118.2	120.0	121.6	124.5	128.6	126.0	118.9
315	101.0	103.8	104.5	108.4	113.0	115.9	119.2	120.8	122.3	124.1	126.4	125.8	117.6
400	101.1	104.3	104.9	109.0	113.8	116.8	119.7	120.9	122.1	124.6	127.6	123.4	116.3
500	101.0	103.8	104.5	109.2	114.4	117.2	120.0	121.2	122.4	124.4	126.3	121.6	113.9
630	100.9	103.8	104.6	109.7	114.7	117.8	120.4	121.5	122.8	124.4	125.5	120.1	112.5
800	100.3	103.0	104.3	110.0	115.0	117.9	120.2	121.3	122.5	123.7	123.9	118.3	110.6
1000	99.7	102.5	104.6	110.6	115.5	118.7	120.4	121.3	122.1	122.6	122.4	117.0	109.1
1250	98.2	101.6	103.1	109.9	115.0	118.1	119.7	120.5	121.1	121.2	121.2	115.5	107.7
1600	96.9	100.3	102.1	109.3	114.5	117.4	118.6	119.4	120.4	120.0	120.0	114.1	106.1
2000	95.2	99.0	101.2	109.0	114.2	117.3	117.7	118.5	118.9	118.9	119.1	112.6	104.3
2500	93.1	97.6	100.1	108.0	113.4	116.4	116.9	117.4	115.4	117.6	117.6	111.0	102.0
3150	90.5	95.7	98.2	106.7	112.4	114.6	115.3	115.9	115.4	115.9	115.8	108.7	99.5
4000	88.5	94.0	96.5	106.1	111.5	114.1	114.7	114.9	115.6	114.9	114.8	107.2	97.2
5000	86.4	92.0	94.5	103.9	110.4	112.2	112.7	113.3	113.3	113.7	113.6	105.9	94.4
6300	85.1	89.2	92.0	103.0	109.4	112.1	112.5	112.9	113.9	114.1	113.6	104.8	93.0
8000	84.2	87.4	89.3	100.1	107.0	109.9	111.0	112.0	110.9	112.8	113.4	103.6	90.8
10000	------	86.5	86.7	96.3	104.4	108.0	109.1	109.9	110.1	110.9	110.8	101.8	90.5
OASPL	112.1	114.6	115.5	121.1	126.2	129.0	131.1	132.3	133.7	135.4	137.1	136.4	131.1
PNL	120.5	124.0	125.7	132.8	138.1	141.0	142.2	143.1	143.6	144.6	145.5	141.9	135.0

TABLE 6.—Continued

(c) Reduced zone 5 (test 8)

One-third OBCF, Hz	θ, deg												
	30	40	50	70	90	100	110	115	120	125	130	140	150
	SPL, dB												
50	94.8	96.7	96.8	100.6	103.7	105.1	106.3	109.1	111.5	113.9	115.2	120.7	118.1
63	97.5	97.7	98.7	102.9	106.8	107.2	109.0	111.3	114.7	117.5	119.4	124.5	119.8
80	98.2	99.9	100.4	104.1	107.1	109.3	111.7	114.5	117.7	120.7	122.6	126.9	120.4
100	99.8	102.1	102.2	105.6	109.2	112.0	114.3	116.4	119.1	122.0	123.7	128.3	122.0
125	100.8	102.8	103.0	107.1	110.5	113.5	115.8	118.1	121.0	123.2	123.7	126.9	123.9
160	100.6	102.4	103.3	107.7	111.2	113.9	116.7	119.5	123.4	126.2	126.9	123.6	123.6
200	101.3	103.2	104.3	108.6	112.6	115.6	118.4	120.7	124.8	128.5	129.6	125.4	121.6
250	102.0	104.0	105.0	109.7	113.7	116.4	119.6	121.2	124.0	127.7	130.7	127.5	119.9
315	102.3	104.7	106.1	110.0	114.3	117.3	120.6	122.2	124.8	128.2	129.1	127.1	119.2
400	102.3	105.0	106.1	110.6	114.8	118.0	121.3	122.5	124.4	128.0	130.4	125.2	118.1
500	102.7	104.8	106.4	111.0	115.2	118.4	121.6	122.6	124.4	127.2	128.8	123.9	116.1
630	103.0	105.1	106.4	111.2	115.6	118.9	121.7	123.0	124.3	126.3	128.0	122.7	114.8
800	102.8	105.1	106.9	111.5	115.8	119.0	121.5	122.5	123.6	125.6	126.9	121.3	113.2
1000	102.3	104.8	106.9	111.8	115.5	119.2	121.3	122.2	123.2	124.6	125.8	120.5	112.1
1250	101.0	104.0	105.9	111.3	115.0	118.5	120.5	121.4	122.3	123.4	124.6	119.3	110.9
1600	100.4	102.9	105.2	110.9	114.8	117.8	119.6	120.4	121.6	122.0	123.9	118.2	109.7
2000	99.1	101.8	104.5	110.5	114.5	117.2	118.7	119.4	119.8	121.0	123.1	117.1	108.1
2500	97.8	100.8	103.8	109.7	113.7	116.0	117.8	118.1	117.2	119.5	121.8	115.8	106.0
3150	96.1	99.3	102.9	108.9	112.3	114.6	116.1	116.0	115.9	117.7	120.2	113.7	103.8
4000	95.0	98.5	102.3	109.1	111.1	114.0	115.3	114.1	115.0	116.2	119.3	112.4	101.3
5000	93.5	97.3	100.8	107.6	109.3	111.2	112.3	111.5	112.2	114.3	118.4	111.4	98.3
6300	92.6	95.2	99.6	106.5	107.5	109.5	110.5	109.9	110.8	113.9	118.5	110.5	96.8
8000	89.7	93.2	97.9	102.9	104.4	106.3	107.7	108.2	107.1	111.8	118.4	109.7	94.0
10000	88.7	91.1	95.5	98.3	101.9	103.0	105.3	105.4	105.6	109.0	116.0	108.2	92.9
OASPL	113.7	116.1	117.8	122.8	126.5	129.5	131.9	133.1	135.1	137.7	139.5	137.0	131.6
PNL	123.9	126.6	129.2	134.7	138.2	140.8	142.8	143.4	144.3	146.5	148.7	144.2	136.4

TABLE 6.—Continued

(d) Maximum zone 5

One-third OBCF, Hz	θ, deg												
	30	40	50	70	90	100	110	115	120	125	130	140	150
	SPL, dB												
50	96.6	99.5	101.1	104.2	107.4	111.4	113.5	115.7	117.3	114.4	119.3	122.6	113.3
63	99.1	100.2	102.2	105.3	109.4	110.8	113.3	116.7	118.5	117.6	121.5	125.0	116.1
80	100.1	101.5	103.3	106.5	109.5	113.4	116.9	119.6	121.5	121.0	125.7	128.0	117.9
100	100.5	102.1	104.2	106.9	110.1	113.0	115.9	118.2	121.3	122.4	127.0	129.5	119.7
125	101.2	102.9	104.5	108.2	111.7	114.4	116.0	118.1	121.2	122.7	126.1	129.1	121.5
160	100.9	103.3	105.2	109.1	112.6	115.7	118.4	120.3	123.5	125.1	126.3	127.5	122.1
200	101.3	103.4	105.8	109.4	113.6	116.8	119.3	122.0	125.7	128.0	129.2	125.1	121.0
250	101.3	103.8	106.3	110.2	114.2	117.2	119.6	121.8	125.3	127.3	131.4	125.2	119.2
315	101.6	104.5	107.1	110.5	114.5	117.7	120.5	122.5	124.9	127.0	129.6	124.3	118.3
400	101.9	104.8	107.2	110.9	115.1	118.6	121.0	122.8	125.4	127.3	129.4	122.6	116.7
500	101.6	104.5	107.3	111.0	115.6	118.9	121.3	122.8	125.2	126.6	128.1	120.8	115.0
630	101.5	104.4	107.4	111.5	115.8	119.5	121.8	123.0	125.1	126.2	126.7	119.6	113.5
800	100.9	103.5	107.0	111.6	115.8	119.3	121.6	122.9	124.5	125.2	125.1	117.7	111.7
1000	100.1	102.9	106.9	111.8	115.7	119.6	121.6	122.6	124.1	124.4	124.2	116.4	110.1
1250	98.9	102.0	105.9	111.3	115.2	119.1	121.0	121.8	123.1	122.9	122.8	114.9	108.3
1600	98.1	100.6	104.9	110.7	114.7	118.4	119.8	120.8	122.4	121.8	121.6	113.3	106.6
2000	96.1	99.0	103.7	109.8	114.0	117.8	118.9	119.7	120.7	120.8	120.7	111.7	104.4
2500	94.1	97.5	102.3	108.6	112.9	116.7	117.6	118.4	118.0	119.5	119.2	109.6	101.7
3150	91.9	95.3	100.2	106.9	111.6	114.7	115.6	116.5	117.1	117.7	117.4	106.7	98.7
4000	90.3	93.5	98.0	105.8	110.3	113.9	114.9	115.3	117.0	116.5	116.4	104.5	95.7
5000	87.8	91.3	95.6	103.3	108.9	111.6	112.7	113.6	114.3	115.1	115.2	102.4	92.2
6300	86.6	88.5	93.2	101.8	107.4	111.0	112.3	113.2	114.3	115.1	115.0	100.5	90.1
8000	85.6	86.8	90.7	98.7	104.6	108.5	110.6	112.1	111.1	113.5	114.5	97.8	88.1
10000	------	86.3	88.5	94.7	101.7	106.1	108.7	110.1	109.9	111.2	112.0	95.2	------
OASPL	112.9	115.3	118.2	122.7	126.8	130.2	132.3	133.9	136.1	137.3	139.2	136.9	129.7
PNL	121.4	124.2	128.0	133.6	138.0	141.6	143.1	144.3	145.5	146.4	147.3	141.0	134.4

TABLE 6.—Continued

(e) Adjusted zone 4

One-third OBCF, Hz	θ, deg												
	30	40	50	70	90	100	110	115	120	125	130	140	150
	SPL, dB												
50	93.9	95.8	95.1	98.8	103.6	105.9	106.9	109.6	111.5	113.4	114.1	119.0	117.5
63	97.4	98.1	97.6	101.3	106.8	108.0	109.8	112.3	114.7	117.1	118.7	122.8	119.5
80	99.0	100.3	100.3	103.7	108.4	112.4	116.7	119.2	121.3	123.5	124.9	127.1	121.1
100	99.3	101.1	100.3	103.7	108.4	110.5	113.2	115.3	117.6	120.2	122.7	127.2	121.9
125	99.8	101.0	100.6	105.1	109.5	111.7	113.8	115.5	117.8	120.0	121.7	126.6	123.2
160	99.4	101.3	101.0	105.9	110.2	112.7	115.2	117.1	119.5	121.7	123.4	123.2	123.1
200	100.1	101.6	102.2	106.3	111.7	114.0	117.0	118.9	121.3	123.6	126.2	124.1	121.9
250	100.3	102.2	102.9	107.7	112.1	115.1	117.6	119.0	120.5	122.6	126.7	126.3	119.7
315	101.1	103.4	104.1	108.2	112.3	115.3	118.4	120.1	121.4	122.4	124.9	126.3	118.6
400	100.6	104.1	104.5	108.9	113.4	116.4	119.0	120.4	121.1	122.9	126.0	123.9	117.2
500	100.6	103.7	104.7	109.2	114.0	116.8	119.6	120.5	121.5	123.0	125.0	122.6	115.0
630	100.8	103.6	104.7	109.8	114.7	117.6	120.1	120.8	121.8	123.0	124.7	120.8	113.4
800	100.1	102.9	104.7	110.2	115.2	118.1	120.0	121.0	121.8	122.6	123.4	119.1	111.7
1000	99.3	102.2	105.1	111.2	116.1	118.8	120.4	121.0	121.9	122.1	122.1	117.9	110.3
1250	97.2	101.0	103.0	109.8	115.0	118.0	119.6	120.2	120.7	120.6	120.7	116.6	108.8
1600	95.9	99.5	102.1	109.4	114.6	117.6	118.7	119.2	120.2	119.4	119.6	115.2	107.2
2000	94.1	97.9	100.9	109.3	114.3	117.7	118.1	118.5	118.7	118.4	118.7	113.9	105.5
2500	91.2	95.7	99.5	107.9	113.5	116.6	117.2	117.6	115.3	117.2	117.4	112.5	103.4
3150	87.5	92.8	96.9	106.2	112.2	114.8	115.7	116.0	115.4	115.6	115.7	110.3	101.3
4000	84.2	90.2	94.5	105.0	111.1	114.1	114.9	114.9	115.6	114.5	114.7	109.0	99.1
5000	83.1	87.8	91.7	102.3	109.8	112.0	112.9	113.5	113.3	113.3	113.5	107.9	96.5
6300	82.5	85.2	88.8	100.8	108.7	111.8	112.7	113.1	114.0	113.7	113.5	107.0	95.4
8000	------	84.1	86.2	97.7	106.0	109.6	111.1	112.3	111.1	112.5	113.4	105.9	93.0
10000	------	------	84.5	93.5	103.2	107.7	109.4	110.4	110.4	110.6	110.8	104.4	92.1
OASPL	111.6	114.1	115.2	120.9	126.0	128.9	130.8	131.9	133.0	134.2	136.1	136.0	131.2
PNL	119.4	122.6	125.0	132.4	138.0	140.9	142.2	143.0	143.2	143.9	144.8	142.4	135.7

TABLE 6.—Concluded

(f) Reduced zone 5 (test 11)

One-third OBCF, Hz	θ, deg												
	30	40	50	70	90	100	110	115	120	125	130	140	150
	SPL, dB												
50	93.8	95.9	96.2	100.1	103.3	105.0	106.0	108.8	111.5	114.0	114.5	120.2	117.8
63	97.3	98.2	98.6	102.8	106.3	107.5	109.7	112.0	114.7	117.1	118.5	123.7	120.0
80	99.4	100.4	101.1	104.4	106.8	109.9	112.7	115.3	118.1	120.5	122.2	126.6	122.2
100	101.0	102.6	102.7	105.4	108.5	112.0	114.3	116.4	119.1	121.7	123.3	127.9	123.5
125	101.4	103.0	102.9	106.9	110.2	112.6	115.5	117.3	120.1	122.4	123.3	125.6	124.8
160	101.4	102.8	103.2	107.6	110.8	113.3	116.5	119.0	122.4	125.2	126.2	122.6	124.3
200	102.2	103.4	104.4	108.1	112.1	115.3	118.3	120.6	123.9	127.2	129.2	125.2	122.4
250	102.4	104.1	105.3	109.6	113.1	115.9	119.2	120.6	123.2	126.2	129.1	127.3	120.2
315	102.7	104.9	106.3	110.2	113.5	116.4	119.8	121.7	123.8	126.5	127.5	126.9	120.5
400	102.8	105.3	106.3	110.5	114.2	117.1	120.6	122.0	123.5	126.2	128.4	124.9	119.4
500	103.7	105.0	106.3	110.6	114.5	117.5	120.8	122.3	123.8	125.8	127.0	123.7	117.3
630	104.1	105.5	106.5	111.2	114.7	117.7	121.0	122.6	123.6	125.3	126.6	122.4	116.1
800	104.1	105.4	107.2	111.7	114.9	118.0	120.5	122.0	123.2	124.8	125.4	121.1	114.8
1000	103.3	105.0	106.8	112.1	115.0	118.1	120.2	121.5	122.5	123.8	124.4	120.1	113.8
1250	102.1	104.2	105.8	111.4	114.4	117.4	119.2	120.5	121.5	122.5	123.2	119.1	113.0
1600	101.6	103.3	105.2	111.1	114.0	116.7	118.3	119.5	120.7	121.2	122.3	118.0	111.9
2000	100.3	102.4	104.6	110.8	113.9	116.2	117.4	118.3	119.0	120.0	121.3	117.1	110.3
2500	98.8	101.0	103.8	109.8	113.0	115.0	116.7	116.9	116.2	118.3	119.8	115.8	108.3
3150	96.9	99.4	102.9	109.2	111.8	113.8	114.8	114.4	114.6	115.7	117.9	113.7	106.1
4000	95.5	98.5	102.7	109.5	110.9	113.4	113.6	112.5	113.6	113.7	116.6	112.3	103.8
5000	93.8	97.3	101.6	107.6	109.2	110.5	110.1	110.2	110.8	111.1	115.3	111.3	100.7
6300	92.9	95.4	100.5	106.4	107.3	108.9	108.4	109.0	109.4	110.4	115.0	110.3	98.7
8000	90.0	93.8	99.2	102.7	103.9	105.3	106.5	107.4	106.2	108.9	114.6	109.6	95.2
10000	89.3	92.1	96.9	98.8	101.1	102.4	103.5	104.6	104.7	106.5	111.9	107.7	93.1
OASPL	114.6	116.3	117.9	122.8	125.9	128.6	131.1	132.6	134.3	136.5	138.1	136.6	132.6
PNL	124.7	126.9	129.3	134.9	137.6	139.9	141.7	142.5	143.4	145.1	146.9	143.9	137.8

TABLE 7.—FLYOVER NOISE DATA

[152-meter (500-foot) flyover, ground microphones, standard day]

(a) Military power (test 12), rated NPR

One-third OBCF, Hz	θ, deg														
	20	30	40	50	60	70	80	90	100	110	120	130	140	150	160
	SPL, dB														
50	------	------	77.2	79.9	84.2	81.9	83.4	82.9	82.8	82.3	84.5	89.5	92.6	89.8	86.4
63	------	------	82.6	83.5	84.7	86.0	85.2	84.5	84.2	89.5	88.9	89.4	94.2	91.3	89.7
80	74.7	82.4	83.5	83.6	84.3	85.6	86.9	87.0	86.7	89.2	93.2	94.6	96.0	96.4	91.0
100	76.0	77.8	83.2	84.7	87.6	86.3	87.7	87.4	88.7	90.3	95.0	98.8	99.0	97.8	91.4
125	79.4	82.9	85.5	87.3	88.3	87.1	88.5	89.1	90.8	92.2	97.7	99.8	100.1	100.3	95.0
160	77.6	82.4	85.8	87.7	88.6	89.3	90.0	91.2	93.4	95.3	96.2	99.6	101.0	100.4	95.0
200	78.7	83.0	86.5	87.6	89.9	91.8	91.7	93.6	95.5	97.1	98.0	101.1	103.2	100.3	95.7
250	81.3	84.9	87.5	89.9	91.8	92.8	93.3	94.6	96.4	97.5	98.3	101.1	100.9	99.1	94.1
315	82.2	86.9	90.0	92.4	93.6	94.3	94.0	94.7	95.6	96.0	98.0	99.2	98.9	98.4	92.3
400	85.0	90.2	92.2	93.0	92.4	92.5	92.7	94.2	95.0	96.3	98.2	98.0	97.3	95.5	90.5
500	85.4	89.3	91.1	92.9	91.8	92.5	92.7	94.1	95.7	96.6	97.8	96.9	95.8	93.0	89.3
630	95.7	96.5	95.9	95.1	93.2	92.2	92.7	94.4	95.8	95.9	96.8	95.8	94.1	91.1	86.7
800	91.9	97.2	99.2	98.4	97.5	95.3	94.5	94.4	95.4	96.1	96.5	95.1	92.4	89.7	83.6
1000	87.2	93.9	96.1	96.7	97.5	96.4	94.5	93.9	94.6	96.0	95.4	93.8	91.2	87.4	81.2
1250	86.0	90.2	92.5	92.6	93.6	94.8	95.2	93.9	94.7	94.5	94.5	92.4	90.6	85.8	81.1
1600	84.4	89.8	92.3	93.3	93.1	93.0	94.4	95.3	95.1	95.2	93.7	91.3	88.8	84.3	78.7
2000	82.5	87.4	90.1	91.4	93.0	93.1	93.7	94.6	96.2	95.6	93.2	89.8	86.7	82.0	76.1
2500	82.6	86.1	88.8	90.3	91.4	92.6	93.9	94.9	96.6	95.9	92.8	88.3	84.5	79.6	73.5
3150	------	89.2	88.0	88.3	90.1	90.9	92.5	93.3	94.2	94.0	90.5	86.4	81.9	77.0	71.2
4000	------	84.3	85.7	87.0	88.6	88.3	88.8	88.7	89.1	89.3	87.7	84.3	80.4	75.6	------
5000	------	81.2	81.6	82.6	84.6	84.6	84.2	83.5	83.9	84.9	84.0	80.7	76.5	73.4	------
6300	------	------	------	81.1	81.1	80.3	80.8	81.7	82.9	81.7	80.1	77.8	------	------	------
8000	------	------	------	------	------	------	80.1	80.2	81.0	80.2	------	------	------	------	------
OASPL	99.1	103.6	104.6	105.0	105.3	105.2	105.4	106.1	107.2	107.9	108.6	109.6	109.9	108.4	103.3

(b) Maximum zone 5 (test 13), rated NPR

One-third OBCF, Hz	θ, deg														
	20	30	40	50	60	70	80	90	100	110	120	130	140	150	160
	SPL, dB														
50	79.3	86.1	87.4	89.7	93.1	91.8	94.9	97.3	96.9	100.7	105.6	105.5	105.7	104.0	98.6
63	84.4	88.2	86.8	91.3	95.0	95.9	98.1	98.4	97.3	101.5	107.2	107.8	107.0	104.4	99.5
80	84.3	91.4	92.6	92.4	93.3	95.6	97.9	101.0	104.9	107.8	112.1	110.1	107.6	103.7	97.3
100	85.0	90.2	93.7	96.1	96.7	98.1	98.8	99.9	101.9	107.2	110.1	111.9	108.6	102.3	99.3
125	88.5	91.3	95.9	95.5	97.3	98.3	99.9	101.2	102.3	107.9	112.8	114.3	109.5	106.1	99.3
160	89.2	92.2	96.3	97.0	98.6	99.5	101.7	103.3	105.5	108.1	114.0	114.8	110.2	105.5	100.0
200	89.3	93.4	96.7	97.6	99.9	99.7	102.5	103.5	105.2	108.4	116.0	115.5	110.6	105.7	98.1
250	90.6	94.7	97.0	99.1	100.2	101.5	102.7	103.8	106.9	110.2	115.8	113.7	110.5	104.6	96.4
315	88.0	92.8	97.5	98.9	100.4	102.1	103.2	104.9	107.3	110.5	115.0	114.3	108.7	102.6	93.7
400	90.1	94.9	97.4	99.6	101.0	103.1	103.2	105.6	107.5	110.2	114.7	112.9	107.2	101.8	93.8
500	94.6	98.7	100.3	100.6	101.7	102.8	104.5	105.9	108.3	110.3	114.7	111.9	106.4	100.4	92.2
630	89.1	100.1	105.4	107.3	104.8	103.1	103.8	105.5	107.9	109.9	113.2	110.3	104.9	98.3	90.8
800	87.4	96.8	104.0	107.3	108.4	106.5	105.3	106.3	108.3	109.7	112.5	109.2	103.9	97.0	89.1
1000	85.0	93.8	99.8	103.3	105.7	107.5	106.4	106.3	107.3	108.7	111.2	107.9	102.2	95.4	87.4
1250	84.6	93.8	99.5	101.7	102.4	104.3	106.1	106.0	106.3	107.4	109.8	106.3	100.8	93.6	86.3
1600	83.8	93.6	98.7	101.9	102.8	103.9	105.1	106.4	106.5	107.1	109.3	106.2	99.8	93.2	84.9
2000	82.7	93.6	97.9	100.3	102.1	103.7	104.7	106.0	106.7	106.7	108.6	105.1	99.0	92.0	82.2
2500	------	91.9	96.1	99.2	100.8	103.6	105.4	106.7	107.2	107.1	108.5	103.9	97.1	89.8	80.4
3150	------	91.1	94.5	97.8	99.8	102.0	104.1	105.2	105.9	105.7	107.5	103.6	95.7	88.4	77.9
4000	------	89.3	93.8	97.8	98.5	100.0	100.5	101.1	102.1	103.6	107.2	103.8	96.1	87.6	77.3
5000	------	85.9	90.1	94.4	95.4	96.8	96.9	97.1	97.9	100.6	105.8	102.8	93.4	84.3	------
6300	------	------	------	93.1	93.1	93.4	94.3	96.4	98.2	99.0	104.0	101.9	------	------	------
8000	------	------	------	------	------	93.1	93.9	------	------	------	------	------	------	------	------
OASPL	100.6	107.2	111.7	114.0	114.9	115.6	116.4	117.5	119.1	121.2	125.4	124.2	119.7	114.8	108.3

TABLE 7.—Continued

(c) Maximum zone 4 (test 14), rated NPR

One-third OBCF, Hz	θ, deg														
	20	30	40	50	60	70	80	90	100	110	120	130	140	150	160
	SPL, dB														
50	79.0	85.4	86.3	84.9	91.3	90.2	91.6	93.7	95.9	97.2	102.9	104.6	104.2	100.9	95.6
63	83.1	89.3	88.5	90.4	91.6	93.6	94.6	95.1	96.9	101.0	105.3	107.4	106.9	104.9	98.8
80	83.3	87.2	90.9	92.1	93.3	94.9	95.8	99.7	100.5	104.9	106.3	108.8	107.1	104.4	96.9
100	85.1	87.1	91.0	95.3	96.7	95.9	97.9	98.2	99.2	102.0	110.3	110.1	109.3	103.7	98.9
125	86.2	89.7	93.2	94.2	96.6	97.7	99.2	100.3	99.4	104.1	109.2	111.5	109.0	106.8	100.4
160	87.4	90.1	94.2	97.2	95.6	98.9	100.2	99.5	100.9	106.7	110.0	111.9	108.9	107.8	97.8
200	87.8	92.5	95.3	96.9	99.3	99.7	101.3	101.5	102.3	105.8	108.9	113.0	110.1	105.1	100.5
250	87.7	92.7	95.3	97.8	98.8	100.5	101.2	102.4	103.4	106.9	108.4	111.3	110.6	105.1	98.3
315	86.5	93.1	96.0	98.2	99.0	100.4	101.6	103.0	105.4	106.7	108.2	111.4	110.2	103.4	95.8
400	88.7	94.0	96.7	98.8	99.4	101.2	102.8	104.3	105.5	107.6	108.7	111.3	108.6	103.0	94.0
500	91.7	96.4	97.7	99.0	100.4	101.8	103.2	104.7	106.3	108.0	108.2	111.0	107.3	103.8	92.1
630	92.4	103.2	104.2	102.1	101.2	101.8	103.2	104.3	106.6	107.3	107.9	110.2	105.8	99.1	90.8
800	89.0	98.9	103.3	105.7	106.2	103.1	103.4	105.2	106.5	107.2	108.5	108.3	104.1	97.7	89.0
1000	87.3	95.1	99.0	102.3	105.4	106.2	103.9	105.4	107.1	106.6	107.5	107.3	102.4	95.8	86.9
1250	86.3	96.0	99.2	99.7	102.2	103.9	105.7	105.0	105.1	105.1	106.2	106.2	101.3	94.1	85.4
1600	85.1	94.8	98.5	101.7	102.5	102.2	104.7	105.5	105.5	104.8	105.0	105.6	100.8	93.2	84.0
2000	84.8	94.2	97.0	99.2	101.8	103.2	104.6	106.0	105.9	104.9	104.1	104.4	99.3	92.1	82.4
2500	83.9	92.6	95.4	98.5	101.2	103.5	105.4	107.2	107.1	105.3	104.2	103.6	97.9	90.3	80.2
3150	------	95.1	94.5	97.2	100.0	102.1	103.8	105.4	105.8	104.1	103.0	102.8	97.0	89.8	77.8
4000	------	90.8	93.7	97.2	99.0	100.2	101.1	102.0	102.7	101.6	102.4	102.9	97.6	88.1	77.6
5000	------	87.2	90.3	93.6	96.1	97.9	97.6	97.6	97.8	98.9	100.5	102.1	95.2	84.7	-----
6300	------	92.0	90.6	92.2	94.0	94.6	94.8	96.8	97.3	96.7	98.7	101.2	------	------	-----
8000	------	------	------	------	92.6	93.4	94.1	96.2	------	------	------	------	------	------	-----
OASPL	100.0	108.1	110.6	112.3	113.8	114.5	115.6	116.7	117.5	118.6	120.5	122.3	119.8	115.6	108.5

(d) Reduced zone 5 (test 15), rated NPR

One-third OBCF, Hz	θ, deg														
	20	30	40	50	60	70	80	90	100	110	120	130	140	150	160
	SPL, dB														
50	78.8	82.6	84.8	88.9	88.3	90.7	91.7	92.3	94.0	93.5	98.5	103.7	103.8	101.8	96.6
63	84.0	88.4	88.4	91.3	92.4	92.7	92.7	93.0	92.7	96.0	101.2	105.9	106.3	105.0	98.9
80	82.2	89.1	89.0	91.5	92.3	93.5	94.9	94.7	97.7	101.0	104.6	108.5	108.7	103.4	100.4
100	83.4	89.2	92.6	92.2	94.7	95.5	95.8	97.5	99.7	101.5	105.9	111.1	108.9	104.1	100.0
125	85.6	91.1	93.5	94.4	95.9	96.0	99.1	100.4	99.0	101.5	107.7	111.4	110.7	106.1	100.0
160	87.5	89.9	94.2	95.4	96.7	97.5	100.1	99.2	101.5	104.7	109.0	111.3	111.4	107.2	100.0
200	89.9	92.9	94.6	95.1	97.2	98.5	98.7	101.3	102.6	105.7	110.2	112.1	111.3	106.9	100.6
250	86.4	91.3	93.5	96.8	98.6	99.2	100.1	101.8	103.4	106.4	110.2	113.0	111.5	106.6	98.7
315	85.7	92.0	95.6	97.6	98.9	100.8	100.7	102.7	104.5	106.9	109.5	112.0	110.4	106.0	97.9
400	88.0	93.6	96.3	99.4	99.0	99.8	100.9	103.3	104.8	107.3	109.1	112.2	109.5	103.7	95.7
500	91.2	97.2	98.0	99.5	99.1	100.4	102.2	103.5	105.6	107.4	108.6	112.1	108.7	102.3	94.5
630	93.2	102.1	104.3	103.7	102.9	101.1	102.6	103.7	105.5	107.0	108.4	111.0	107.7	101.1	92.5
800	97.8	97.8	102.7	105.5	106.0	105.0	103.0	103.7	105.4	107.2	108.5	109.9	105.8	99.5	91.5
1000	86.4	95.6	99.2	101.5	103.7	106.4	106.3	104.6	105.7	106.2	107.4	108.8	104.0	97.6	89.9
1250	86.5	96.1	100.2	101.3	100.6	103.3	104.9	103.8	104.2	105.1	106.6	107.9	103.1	96.5	87.6
1600	84.6	94.1	98.9	101.3	102.8	102.7	103.3	104.5	105.1	104.9	105.5	106.8	102.5	95.7	86.3
2000	82.9	93.1	97.4	99.9	101.2	102.9	103.9	104.4	105.8	105.3	105.2	106.3	102.0	94.8	84.7
2500	------	91.8	95.9	98.5	100.8	103.1	104.2	105.2	106.4	106.3	105.2	105.8	99.8	93.1	82.5
3150	------	91.4	94.9	98.0	99.7	101.5	102.8	104.1	105.1	104.4	103.6	104.7	99.1	91.5	80.8
4000	------	90.1	94.4	97.6	99.2	99.6	100.2	100.4	101.3	101.5	102.3	104.7	99.7	91.3	79.6
5000	------	87.6	90.4	94.3	95.9	97.1	97.7	96.3	96.8	97.6	100.3	103.4	98.6	88.3	79.5
6300	------	------	------	93.4	93.8	94.5	94.4	95.0	97.0	96.9	97.8	103.0	------	------	------
8000	------	------	------	------	93.1	92.5	93.5	94.2	96.5	96.6	97.5	------	------	------	------
OASPL	99.6	107.5	110.7	112.5	113.4	114.3	114.9	115.5	116.9	118.2	120.3	122.9	120.9	116.1	109.6

TABLE 7.—Continued

(e) Military power (test 16), downtrimmed NPR

One-third OBCF, Hz	θ, deg 20	30	40	50	60	70	80	90	100	110	120	130	140	150	160
	SPL, dB														
50	-----	73.8	75.4	78.8	80.6	82.3	80.8	79.9	82.2	81.6	83.4	84.0	85.4	86.5	84.2
63	-----	80.9	81.3	82.7	82.4	83.6	84.5	84.2	84.2	82.6	86.0	87.3	87.5	85.6	85.1
80	74.3	79.2	80.8	81.2	82.8	83.4	83.8	84.8	85.7	87.3	87.1	89.3	91.3	89.5	85.5
100	76.7	77.9	80.6	83.2	83.8	82.9	83.3	85.1	86.8	88.0	88.8	91.7	92.8	92.0	87.6
125	78.1	82.3	84.4	84.8	86.3	85.9	86.4	87.9	87.2	89.4	90.8	93.0	93.6	92.9	89.3
160	76.1	80.5	84.2	85.9	87.7	88.3	89.1	89.3	89.5	92.4	92.5	93.4	93.8	93.3	90.6
200	78.9	82.8	85.0	88.4	89.3	89.7	91.6	92.1	92.5	92.7	93.2	93.5	94.1	92.2	88.0
250	79.7	83.8	87.0	89.4	91.7	91.9	92.1	92.1	92.2	92.3	92.1	92.4	91.7	89.8	84.9
315	83.8	87.3	90.3	91.2	92.1	90.9	90.1	90.1	91.2	92.0	92.0	92.0	90.2	87.6	82.5
400	83.7	89.0	90.4	90.9	89.4	89.1	90.3	90.8	91.2	91.5	91.4	90.4	88.9	85.6	81.5
500	82.7	86.2	89.3	89.7	89.7	89.8	89.8	91.0	91.5	91.8	91.8	89.6	88.0	84.0	79.8
630	81.1	85.6	88.2	88.1	88.1	89.0	90.1	90.9	90.5	91.7	91.1	89.2	86.2	82.5	77.3
800	80.2	85.3	87.1	87.5	88.9	89.9	89.5	90.4	90.9	91.3	89.4	88.0	85.3	81.0	75.5
1000	79.9	84.8	86.6	87.4	87.6	88.0	88.2	89.1	89.9	89.8	88.6	86.6	83.9	79.6	75.5
1250	79.9	84.4	85.3	86.2	86.3	87.1	87.3	87.7	88.1	88.6	87.4	85.6	82.7	78.3	74.9
1600	79.3	82.6	85.1	86.1	86.8	87.4	87.7	88.0	88.1	87.9	86.6	84.1	81.6	76.9	72.5
2000	78.7	82.1	83.9	84.6	86.1	87.2	88.0	88.5	88.2	88.0	86.1	82.9	79.5	75.0	69.9
2500	-----	83.3	85.3	86.0	87.3	87.6	87.8	88.9	88.5	87.2	85.0	80.9	77.5	73.2	69.1
3150	-----	87.5	87.3	83.5	84.0	85.8	87.4	87.9	87.5	85.7	82.8	79.0	75.2	71.4	67.6
4000	-----	82.2	82.8	82.0	82.4	83.1	83.0	83.2	83.5	82.2	80.9	77.6	74.5	70.9	-----
5000	-----	80.9	79.2	79.0	78.9	79.7	79.2	78.7	78.9	78.8	77.5	74.2	72.1	70.6	-----
6300	-----	--	------	------	77.1	76.2	76.6	77.2	76.7	75.2	74.6	73.7	-----	-----	-----
OASPL	92.0	97.4	99.3	100.0	100.8	101.0	101.5	102.0	102.3	102.8	102.6	102.5	102.3	100.7	97.0

(f) Maximum zone 5 (test 17), downtrimmed NPR

One-third OBCF, Hz	θ, deg 20	30	40	50	60	70	80	90	100	110	120	130	140	150	160
	SPL, dB														
50	79.6	82.3	85.7	87.5	89.6	91.4	90.7	96.5	95.4	101.4	102.9	102.7	102.5	103.9	99.0
63	83.4	87.0	88.0	91.1	95.2	94.2	93.7	97.0	98.9	103.3	106.3	105.9	104.3	102.4	96.1
80	85.1	86.0	90.4	90.0	93.2	92.0	96.9	98.9	98.1	100.1	100.8	104.3	103.1	103.2	97.7
100	86.2	88.7	88.9	91.7	95.9	95.0	95.2	97.1	97.8	99.9	104.4	105.4	104.7	103.8	96.1
125	86.9	89.5	92.9	94.3	95.6	96.0	98.0	98.6	98.6	102.2	105.4	105.1	104.2	103.6	97.8
160	85.1	87.7	90.8	94.2	95.2	97.8	99.2	100.9	99.6	102.3	103.3	104.5	104.0	103.4	94.6
200	85.2	88.5	92.0	93.3	95.7	96.6	99.9	99.9	100.4	102.7	103.5	103.7	103.9	103.8	93.4
250	86.2	90.2	93.8	95.2	96.3	98.5	99.3	99.6	102.1	103.5	104.0	102.8	103.5	102.6	97.6
315	86.6	90.5	93.6	95.4	96.8	98.2	99.4	99.9	102.1	103.3	103.3	101.4	102.0	100.8	95.3
400	84.5	90.4	93.9	95.8	96.7	98.7	99.5	101.8	102.7	103.9	103.2	102.5	102.5	100.0	92.7
500	84.7	89.9	93.9	95.7	97.5	99.3	100.8	101.6	102.8	103.8	103.2	103.4	102.7	98.5	91.5
630	82.9	89.4	93.9	95.7	97.1	98.0	100.4	101.3	103.3	103.6	103.4	102.8	101.8	96.0	88.1
800	83.2	88.9	93.0	95.2	97.3	98.4	100.1	101.7	102.8	103.3	102.8	102.4	99.8	93.6	85.4
1000	82.0	88.1	92.9	95.1	97.0	98.0	99.0	100.8	102.2	102.0	102.1	101.2	97.5	91.6	83.2
1250	81.9	87.8	92.9	94.9	96.2	97.2	98.0	100.0	100.6	100.3	100.3	99.4	95.9	90.1	81.8
1600	81.8	89.0	93.1	94.0	95.8	97.5	98.9	100.2	101.2	100.1	99.8	98.4	95.0	88.5	79.9
2000	81.4	88.6	91.7	92.8	95.0	97.2	98.5	99.9	101.0	100.2	99.4	97.7	93.5	86.9	77.2
2500	------	87.0	90.0	92.2	94.3	96.9	98.5	99.8	100.7	99.5	97.6	95.3	91.7	84.7	74.7
3150	------	90.5	89.4	89.8	91.9	94.6	96.8	99.1	99.9	97.7	96.0	93.1	89.0	82.1	72.7
4000	------	84.7	86.6	88.3	90.8	92.2	93.3	94.1	95.9	94.9	94.3	92.9	88.5	80.1	------
5000	------	83.7	82.5	84.0	86.1	87.8	88.7	88.5	89.9	89.7	90.7	89.8	85.6	77.6	------
6300	------	------	------	83.2	83.5	83.9	85.7	87.6	89.9	88.4	87.7	87.9	85.2	------	------
8000	------	------	------	------	------	------	85.6	87.4	89.1	88.0	------	------	------	------	------
OASPL	96.7	101.7	105.0	106.8	108.6	110.0	111.5	112.3	113.9	114.9	115.7	115.5	114.6	113.3	107.4

TABLE 7.—Continued

(g) Maximum zone 4 (test 18), downtrimmed NPR

One-third OBCF, Hz	θ, deg														
	20	30	40	50	60	70	80	90	100	110	120	130	140	150	160
	SPL, dB														
50	78.0	83.7	85.2	87.7	88.3	89.9	91.1	90.7	92.2	97.3	101.5	102.8	101.2	101.5	97.6
63	83.7	86.3	87.7	88.6	90.8	92.0	94.2	95.4	97.3	101.2	103.9	103.7	104.2	101.1	95.7
80	80.8	85.6	87.9	91.3	91.6	93.2	94.5	95.9	95.5	97.7	103.6	102.4	105.0	100.4	96.5
100	84.0	87.4	87.7	93.1	94.0	95.0	94.0	95.1	95.7	99.1	103.3	107.3	107.0	101.9	96.4
125	84.9	88.7	92.8	92.8	94.8	96.4	96.3	97.2	98.9	100.8	104.1	107.0	106.4	104.6	97.6
160	83.5	89.6	92.9	94.9	94.2	95.8	97.2	99.3	100.2	101.8	104.1	106.1	105.4	102.8	98.1
200	82.6	90.5	92.2	95.9	95.8	98.3	97.9	99.7	99.5	103.1	103.2	104.6	103.8	103.5	98.3
250	85.2	91.0	92.6	96.3	97.0	97.8	99.3	99.6	101.2	103.3	104.1	103.2	105.1	103.7	97.7
315	85.2	90.5	94.0	95.6	97.0	98.4	98.7	99.7	101.5	103.5	103.2	102.4	104.3	102.4	95.4
400	84.0	89.2	93.7	96.4	97.2	99.2	99.3	101.4	102.2	103.4	102.8	102.3	104.1	100.3	94.1
500	84.0	89.1	94.1	97.1	97.2	99.0	100.4	102.1	102.8	103.6	103.1	102.6	103.3	98.5	91.3
630	83.2	88.7	94.3	96.4	96.8	98.9	100.5	101.3	103.5	103.8	103.4	102.8	102.1	95.7	88.1
800	82.2	89.2	93.8	95.9	97.3	98.7	100.3	101.8	103.2	104.1	103.5	102.4	100.2	93.7	85.7
1000	81.7	88.7	93.3	95.8	96.5	97.9	99.3	101.2	102.7	103.5	102.4	101.1	97.6	91.6	82.9
1250	80.8	88.9	92.7	96.0	96.3	97.0	98.5	99.4	100.9	101.2	100.7	99.1	96.1	89.3	80.5
1600	80.7	89.2	93.3	95.2	96.0	97.6	99.0	100.2	101.6	101.2	99.8	97.7	94.7	88.0	79.0
2000	79.5	88.6	91.8	94.4	95.3	97.6	99.5	101.0	101.8	100.7	99.2	96.7	93.3	85.3	76.7
2500	-----	87.8	90.6	94.0	95.2	97.6	99.5	101.0	101.9	100.3	98.2	94.7	91.0	83.4	73.9
3150	-----	91.7	90.5	92.1	93.5	95.9	98.5	100.7	101.5	99.1	96.4	92.3	88.4	80.7	71.7
4000	-----	85.0	87.7	91.1	91.7	93.4	94.5	95.4	96.0	95.5	94.6	91.8	88.1	78.8	71.6
5000	-----	81.6	83.0	87.1	88.1	89.2	90.0	90.0	91.0	91.3	91.2	88.1	84.8	74.5	------
6300	-----	------	------	84.2	84.4	84.4	87.2	90.3	91.3	88.7	87.4	85.2	83.8	------	------
8000	-----	------	------	------	84.2	84.0	85.7	88.6	90.1	88.5	86.9	------	------	------	------
OASPL	95.3	101.9	105.1	107.7	108.5	110.1	111.3	112.7	113.9	114.8	115.4	115.8	115.7	112.8	107.2

(h) Reduced zone 5 (test 19), downtrimmed NPR

One-third OBCF, Hz	θ, deg														
	20	30	40	50	60	70	80	90	100	110	120	130	140	150	160
	SPL, dB														
50	-----	81.5	85.0	84.7	86.3	91.0	90.7	94.4	92.6	91.9	96.1	101.4	102.8	99.7	96.2
63	-----	83.8	89.4	88.3	90.7	92.2	95.7	96.3	97.4	99.0	100.6	107.2	104.4	102.2	99.5
80	81.1	85.5	87.3	90.1	90.9	95.3	94.7	99.5	101.5	104.1	101.7	104.2	105.0	102.0	96.9
100	84.5	85.6	90.6	94.0	94.1	95.9	96.5	97.7	99.8	100.5	103.1	106.1	106.4	102.0	97.3
125	84.4	88.7	91.6	93.2	94.8	96.5	96.4	97.6	99.6	99.8	103.1	105.0	106.1	103.2	99.7
160	84.1	89.2	90.0	94.3	94.9	96.2	97.9	98.4	101.5	102.2	103.4	104.5	105.5	101.9	97.6
200	83.7	89.0	91.8	95.6	96.2	97.5	98.4	99.4	101.8	102.9	104.2	102.9	103.3	103.1	97.7
250	87.0	90.2	93.8	96.6	97.2	98.2	98.4	100.4	101.5	103.5	103.1	102.1	103.2	102.7	97.5
315	88.2	91.2	94.5	96.5	97.1	98.2	99.2	101.0	101.7	103.5	102.7	102.1	103.6	102.7	95.3
400	85.9	91.2	94.7	96.8	96.8	98.4	99.4	100.8	103.1	104.2	103.2	102.1	103.2	101.2	95.5
500	86.6	91.2	95.1	96.4	96.8	98.9	100.2	101.9	102.5	103.8	103.1	103.6	103.8	100.2	93.1
630	85.0	89.1	94.3	96.5	97.3	100.1	100.0	101.7	103.6	103.9	103.1	102.9	102.4	98.1	92.8
800	84.4	89.9	94.7	96.0	97.2	98.6	100.4	101.8	103.9	104.1	102.8	102.4	100.8	95.7	87.8
1000	83.1	88.9	94.2	95.4	96.8	97.8	99.2	101.0	102.6	103.2	102.1	101.3	98.9	93.8	85.7
1250	83.5	88.4	93.9	95.2	96.1	96.9	98.3	99.6	101.3	101.8	101.1	100.2	97.1	92.0	83.4
1600	83.0	87.8	93.3	95.0	95.9	97.1	99.5	100.2	102.0	101.7	100.7	99.1	96.1	90.5	82.0
2000	82.3	86.9	92.0	93.5	95.7	97.1	99.6	100.6	102.2	101.9	99.7	98.1	94.9	88.6	79.5
2500	-----	85.2	90.9	92.2	94.9	97.2	99.5	100.6	102.1	101.4	98.7	96.6	93.3	86.3	76.9
3150	-----	90.6	90.3	90.8	92.9	95.8	98.8	100.5	101.6	100.3	96.7	93.8	90.2	84.2	74.2
4000	-----	86.1	91.8	89.5	91.7	93.5	95.1	95.6	96.7	96.8	95.4	94.1	90.3	82.7	------
5000	-----	84.2	90.0	85.3	87.5	89.2	89.8	89.9	91.2	92.5	91.8	90.0	87.5	79.5	------
6300	-----	------	86.6	84.8	84.4	85.1	87.5	90.2	91.3	90.5	88.4	88.4	86.3	------	------
8000	-----	------	------	------	------	------	87.4	89.7	91.1	90.6	88.5	------	------	------	------
OASPL	96.6	101.8	105.8	107.5	108.5	110.1	111.5	112.3	114.6	115.3	114.9	115.7	115.6	112.8	107.9

TABLE 7.—Continued

(i) Adjusted zone 4 (test 20), downtrimmed NPR

One-third OBCF, Hz	θ, deg														
	20	30	40	50	60	70	80	90	100	110	120	130	140	150	160
	SPL, dB														
50	78.4	82.6	84.1	87.7	90.6	91.9	92.9	92.1	94.4	96.8	100.0	101.2	101.7	101.5	95.1
63	82.7	84.4	86.7	89.2	89.2	90.6	92.2	95.0	100.1	101.0	103.3	104.4	104.1	99.3	95.3
80	81.9	84.9	86.5	89.7	91.3	94.1	94.5	98.5	97.9	97.8	99.9	102.5	103.0	100.8	94.6
100	82.4	86.0	89.1	92.0	93.9	93.3	94.1	95.2	97.6	97.9	99.5	103.0	104.1	101.5	96.4
125	84.4	89.2	90.7	92.5	93.9	95.0	96.3	96.6	97.8	100.0	102.6	102.9	102.7	102.0	96.3
160	82.5	87.1	91.7	92.5	95.7	95.4	97.3	99.3	99.5	100.2	102.7	101.9	102.2	101.2	95.0
200	81.9	89.0	92.0	93.7	96.6	97.7	98.7	98.9	99.5	102.3	102.9	101.3	102.2	101.6	95.9
250	83.6	90.7	94.2	96.5	97.4	97.3	98.1	99.1	100.6	102.5	102.5	101.2	99.8	100.9	97.1
315	85.2	91.4	94.6	96.0	97.4	97.9	98.5	100.8	102.0	103.1	101.8	100.5	100.6	100.5	95.1
400	84.5	91.6	94.3	97.3	97.1	97.9	99.3	100.9	102.0	103.0	102.4	100.9	100.9	99.4	93.3
500	84.5	91.6	94.8	96.5	97.4	98.6	100.2	101.5	102.5	103.6	102.7	100.8	102.1	98.8	91.5
630	82.2	90.4	94.3	95.5	97.5	97.9	100.8	102.1	103.3	103.5	102.6	101.5	101.4	96.6	88.5
800	82.9	91.0	93.7	95.9	96.9	98.7	100.7	102.1	103.4	103.2	102.5	101.3	100.1	94.9	85.6
1000	82.0	90.3	93.5	95.6	97.0	98.3	99.7	101.2	102.7	102.2	101.4	99.4	97.4	92.2	83.7
1250	80.7	90.0	93.9	95.3	96.4	97.7	98.6	99.2	100.5	101.0	100.3	98.4	95.9	90.0	80.9
1600	80.2	89.6	93.3	94.7	95.8	97.6	99.0	100.4	101.6	100.8	99.6	97.5	94.5	88.3	79.3
2000	79.5	88.6	92.2	94.0	95.7	98.1	99.6	100.8	101.7	101.2	99.2	95.9	93.5	85.6	77.7
2500	-----	87.2	90.7	92.9	95.5	98.2	99.8	101.3	102.4	101.3	98.3	94.3	91.1	84.2	75.2
3150	-----	91.4	90.0	91.1	93.7	96.5	98.9	101.2	101.4	100.2	96.0	92.0	88.3	81.7	73.0
4000	-----	86.5	88.2	90.0	92.4	94.0	94.4	95.9	96.3	97.0	94.7	91.5	87.9	79.8	72.9
5000	-----	83.0	83.4	85.5	87.7	89.2	89.9	90.5	91.1	92.3	90.8	87.1	84.5	76.0	------
6300	-----	------	------	83.6	84.8	85.4	87.5	91.0	91.1	90.4	86.8	84.3	83.3	------	------
8000	-----	------	------	------	------	------	86.9	89.2	90.1	90.6	86.1	84.0	------	------	------
OASPL	95.0	102.4	105.3	107.2	108.7	109.9	111.4	112.3	114.0	114.5	114.3	113.7	113.6	111.6	106.0

(j) Reduced zone 5 (test 21), downtrimmed NPR

One-third OBCF, Hz	θ, deg														
	20	30	40	50	60	70	80	90	100	110	120	130	140	150	160
	SPL, dB														
50	-----	81.9	85.2	88.2	88.1	88.4	89.0	90.5	92.1	95.3	100.6	99.6	101.1	100.6	95.9
63	-----	84.9	84.8	87.7	88.7	88.1	91.1	92.3	95.2	97.4	102.0	103.7	102.9	101.8	97.1
80	78.2	83.9	86.3	89.6	90.0	92.5	93.5	93.4	96.5	98.9	101.6	103.7	103.4	99.5	95.7
100	79.5	82.7	88.1	92.9	93.7	93.8	94.3	95.6	96.5	98.1	100.3	103.5	104.7	100.8	96.6
125	83.3	86.6	90.2	92.9	93.3	93.6	96.2	96.2	97.0	101.0	103.0	103.7	103.8	103.4	98.8
160	81.5	87.6	90.9	92.6	95.6	96.0	96.2	97.5	98.0	101.2	104.2	104.7	104.6	102.4	98.5
200	80.6	90.6	93.9	94.1	95.7	97.4	96.9	98.2	100.9	101.9	102.4	103.3	104.3	102.4	99.6
250	83.1	90.5	92.8	94.6	96.9	97.3	98.5	99.9	100.6	102.6	102.9	102.1	103.0	102.3	97.4
315	84.7	90.4	93.9	95.0	96.5	97.2	98.6	99.4	102.1	102.8	103.1	101.6	102.5	102.5	97.0
400	82.6	91.2	94.1	95.0	96.9	98.3	98.9	100.5	102.0	103.3	103.1	101.8	102.4	101.0	96.7
500	83.3	92.0	94.5	96.0	97.5	97.7	99.5	100.6	102.4	103.8	103.1	102.5	103.0	99.4	93.6
630	81.2	89.7	94.2	95.5	97.0	98.8	99.1	100.2	102.4	102.9	102.3	102.0	102.3	98.8	90.5
800	80.9	91.3	94.3	94.7	96.3	98.4	99.5	100.8	103.1	103.2	102.7	100.9	100.2	96.3	87.3
1000	79.4	90.4	93.6	94.2	96.3	97.4	98.9	99.8	101.9	102.4	101.3	100.2	98.5	93.6	84.2
1250	78.2	89.8	92.7	93.5	95.8	97.1	98.0	98.7	100.9	101.2	100.0	99.1	96.5	91.2	81.9
1600	77.2	89.5	92.9	93.6	95.3	97.5	98.5	99.8	101.5	101.5	99.7	98.0	95.6	89.9	80.5
2000	77.1	88.6	91.2	92.4	95.2	97.5	99.2	100.3	101.5	101.6	99.0	97.3	94.3	88.3	78.6
2500	-----	87.0	90.3	92.6	94.7	97.7	99.6	100.8	102.4	101.8	98.6	95.8	92.3	86.5	75.6
3150	-----	88.9	90.7	91.2	92.9	96.4	98.2	99.8	101.4	100.4	97.0	93.6	90.5	84.4	73.4
4000	-----	85.2	87.6	89.8	91.6	93.6	94.3	95.1	96.8	97.0	95.2	92.7	90.5	83.1	72.4
5000	-----	82.8	82.9	84.8	87.3	89.3	89.8	90.7	91.9	93.2	92.1	88.8	86.6	78.6	72.3
6300	-----	------	------	83.3	83.6	84.9	86.5	89.3	91.9	90.4	88.6	86.7	84.9	------	------
8000	-----	------	------	------	------	84.8	85.0	87.6	89.9	89.0	86.6	85.8	------	------	------
OASPL	93.1	102.0	105.0	106.4	108.1	109.6	110.7	111.3	113.7	114.5	114.6	114.5	114.6	112.5	107.8

TABLE 7.—Continued

(k) Military power (test 22), downtrimmed NPR

One-third OBCF, Hz	θ, deg														
	20	30	40	50	60	70	80	90	100	110	120	130	140	150	160
	SPL, dB														
50	-----	-----	73.4	85.5	77.9	80.1	80.6	80.9	79.3	79.6	81.5	83.3	82.4	82.4	91.6
63	-----	-----	80.6	88.6	82.3	82.5	82.8	82.2	84.0	84.6	84.4	86.2	86.3	85.7	94.8
80	75.3	77.2	82.2	89.5	85.3	83.6	82.3	83.6	83.6	84.9	86.3	86.9	87.7	90.4	86.7
100	73.9	77.4	81.3	92.8	85.0	83.2	84.1	85.4	84.6	87.2	90.1	90.9	92.4	90.2	87.5
125	78.2	80.3	83.9	93.7	85.0	87.1	88.4	88.3	88.7	88.6	90.2	92.0	92.1	91.8	87.5
160	78.6	81.6	84.8	93.8	87.1	88.4	88.9	89.5	89.5	90.1	91.6	92.2	93.5	92.2	89.5
200	78.5	82.6	85.3	94.0	89.3	89.5	91.7	91.0	92.1	93.5	93.4	92.4	94.1	91.2	89.1
250	80.2	84.6	86.7	93.2	90.7	91.4	91.5	91.9	92.5	92.7	91.5	91.4	91.4	89.4	84.9
315	82.8	87.3	90.9	93.2	92.8	91.6	90.3	90.4	90.5	91.0	91.7	91.3	89.4	86.7	83.2
400	85.3	88.8	91.0	92.3	89.7	89.4	89.6	90.4	90.6	91.4	91.1	90.3	88.6	85.2	81.4
500	83.0	86.3	88.1	91.8	88.3	89.3	89.3	89.8	90.4	91.2	91.1	90.3	87.2	83.9	79.1
630	81.3	86.1	87.3	89.6	87.8	88.5	89.9	90.7	90.3	91.3	89.8	88.1	86.3	82.0	77.3
800	80.9	85.1	87.0	88.9	88.4	89.3	89.6	89.8	90.1	90.8	89.8	87.8	84.9	80.8	75.9
1000	80.1	84.4	86.1	87.6	87.0	87.1	87.6	88.5	89.0	89.4	88.9	86.1	83.8	78.2	74.4
1250	78.8	83.9	85.2	87.2	86.1	86.8	87.0	87.5	87.8	88.2	87.8	85.3	82.2	77.8	73.3
1600	78.0	82.8	84.4	85.9	85.9	87.0	87.3	87.4	87.1	87.3	86.7	84.6	81.7	77.3	72.3
2000	78.1	82.1	83.6	84.4	85.5	87.1	87.6	87.8	87.9	87.4	85.7	83.0	80.2	75.6	69.4
2500	-----	84.1	84.6	82.8	86.4	86.8	87.5	88.1	88.2	87.2	84.9	81.4	77.7	73.6	67.7
3150	-----	89.3	85.8	81.7	83.5	85.1	86.3	86.8	86.7	85.3	82.8	79.9	74.9	71.5	66.7
4000	-----	83.5	82.2	80.9	82.0	82.4	82.8	82.8	82.5	82.6	80.6	78.1	73.9	70.3	-----
5000	-----	80.0	78.4	77.6	78.7	79.2	78.6	77.8	77.1	78.5	77.0	74.6	70.7	69.4	-----
6300	-----	-----	-----	------	76.3	75.4	75.6	75.6	75.4	75.3	73.9	73.4	------	-----	-----
OASPL	92.2	97.5	99.1	103.5	100.5	100.8	101.2	101.5	101.8	102.4	102.3	101.8	101.6	99.9	96.3

(l) Maximum zone 5 (test 23), downtrimmed NPR

One-third OBCF, Hz	θ, deg														
	20	30	40	50	60	70	80	90	100	110	120	130	140	150	160
	SPL, dB														
50	-----	81.8	85.7	85.7	91.2	90.7	93.6	96.5	98.9	101.5	105.8	105.7	104.5	102.9	98.4
63	-----	87.3	86.7	89.8	93.8	94.3	97.5	99.6	102.0	104.4	105.9	105.3	104.2	102.1	97.4
80	80.6	85.6	89.4	92.4	93.3	94.8	97.1	98.4	100.1	100.0	101.5	104.3	104.6	102.0	96.6
100	83.2	86.5	90.7	92.5	94.4	94.8	95.7	96.0	97.8	99.0	103.6	106.9	104.0	103.7	98.1
125	84.6	88.4	90.5	94.3	94.4	95.4	96.0	97.5	99.9	101.1	104.3	104.7	105.0	102.2	98.4
160	84.2	90.1	90.7	94.2	96.0	95.9	98.3	98.5	100.7	100.8	104.0	104.4	104.8	103.3	98.3
200	83.1	90.5	92.1	93.3	97.0	97.5	99.1	99.0	100.8	102.1	101.9	103.3	104.7	103.4	98.5
250	85.3	91.3	92.7	95.0	96.9	97.6	98.2	99.0	100.8	102.9	103.3	103.3	103.8	102.3	97.3
315	86.6	91.0	93.5	95.6	96.5	98.1	98.7	99.9	101.7	103.6	103.1	102.2	101.9	101.8	94.9
400	84.7	90.0	93.2	95.9	97.0	98.3	99.5	100.8	102.3	103.2	103.5	102.1	102.4	99.1	92.6
500	84.4	90.0	94.0	96.3	96.9	98.5	99.4	101.4	103.0	103.6	103.7	103.2	103.2	97.7	90.7
630	84.0	89.5	93.8	96.2	96.6	98.3	100.0	101.3	102.3	103.2	102.2	103.4	101.4	95.4	87.6
800	82.2	89.6	92.1	95.0	95.9	98.0	99.7	101.1	102.7	103.1	102.9	102.4	99.2	93.9	84.9
1000	81.9	89.1	92.2	94.6	95.8	96.9	98.7	100.2	101.2	102.3	102.1	101.1	97.0	91.4	82.5
1250	80.9	89.2	91.8	94.2	95.1	96.6	98.2	99.4	99.9	99.8	100.5	100.0	96.0	89.6	80.2
1600	80.4	88.5	91.6	93.8	95.3	97.1	98.9	99.5	100.3	100.1	99.7	98.1	94.1	88.4	78.5
2000	80.2	87.7	91.1	93.4	94.5	96.9	98.5	99.8	100.6	99.7	98.8	96.7	92.8	86.1	76.3
2500	-----	86.2	89.2	92.4	94.6	96.2	98.7	99.9	100.6	99.4	97.9	95.3	90.7	84.4	74.5
3150	-----	91.4	89.1	89.9	92.1	94.7	97.2	99.2	100.2	98.1	95.8	93.2	88.2	81.8	71.2
4000	-----	84.4	86.0	89.0	90.6	92.4	93.6	94.3	94.9	94.2	94.2	92.9	87.6	79.5	------
5000	-----	80.8	81.4	83.9	86.1	87.8	89.0	88.6	89.7	90.0	90.6	89.2	85.0	76.0	------
6300	-----	------	------	81.8	82.3	83.3	86.2	88.4	90.0	88.1	87.1	86.5	82.3	------	------
8000	-----	------	------	------	------	82.4	84.1	86.5	88.4	86.1	86.6	------	------	------	------
OASPL	95.3	102.0	104.4	106.9	108.3	109.6	111.2	112.4	113.9	114.7	115.6	115.8	115.0	112.8	107.6

TABLE 7.—Continued

(m) Maximum zone 4 (test 24), downtrimmed NPR

One-third OBCF, Hz	θ, deg														
	20	30	40	50	60	70	80	90	100	110	120	130	140	150	160
	SPL, dB														
50	77.1	80.4	85.2	86.5	87.7	92.2	93.0	92.0	95.3	97.9	101.1	102.2	102.5	99.5	94.7
63	81.7	84.5	84.3	90.4	91.1	94.3	93.3	94.6	97.5	99.2	100.2	102.5	102.7	100.7	93.9
80	81.2	85.2	85.9	87.6	92.7	93.9	94.0	94.9	96.3	98.8	101.2	105.0	101.6	101.4	96.7
100	81.5	85.7	89.5	90.8	91.0	90.3	93.2	95.2	95.7	99.0	102.7	103.7	104.9	100.7	97.1
125	81.6	86.5	90.2	91.9	92.7	93.5	95.6	96.3	98.5	102.0	103.3	104.5	105.0	101.1	98.1
160	81.8	88.0	91.2	93.1	95.0	94.3	96.7	96.6	100.9	99.9	102.1	103.3	104.0	103.2	99.2
200	83.6	89.1	92.7	93.4	95.8	96.9	97.3	98.3	100.2	102.6	102.6	103.4	104.1	101.7	99.5
250	84.3	89.6	92.9	95.0	96.2	97.1	98.7	98.8	100.3	101.6	102.5	101.4	103.3	101.7	97.0
315	84.4	90.5	93.3	96.1	95.5	96.8	97.9	100.1	100.5	102.6	102.1	101.6	102.0	100.3	95.0
400	82.7	89.8	92.9	95.9	96.4	97.9	98.2	100.6	101.7	102.6	103.0	100.9	101.8	99.4	93.7
500	82.9	90.1	93.1	96.0	96.5	97.6	99.9	100.6	102.0	103.5	102.4	102.5	101.6	98.2	91.6
630	81.4	89.9	93.8	95.3	96.2	97.5	99.3	100.9	102.6	103.2	102.4	101.8	100.6	95.5	88.4
800	81.2	89.6	93.0	94.5	95.8	97.7	99.3	100.6	102.4	102.7	101.9	101.2	99.0	93.2	86.1
1000	80.5	89.4	92.2	94.6	95.3	96.9	98.8	99.7	102.4	101.7	101.3	99.4	96.7	91.3	84.0
1250	80.3	89.4	92.7	94.1	95.0	96.5	97.4	98.8	99.9	99.9	99.7	97.9	94.5	88.9	81.7
1600	80.8	89.2	92.2	93.5	94.9	96.3	98.1	99.2	100.3	99.5	98.7	96.8	93.1	87.6	79.8
2000	79.2	87.9	90.3	92.5	94.1	96.2	98.2	99.6	100.7	99.8	98.2	95.2	91.8	85.9	77.7
2500	79.6	86.1	89.4	90.9	94.3	96.1	98.1	99.9	100.8	99.0	97.2	93.8	89.5	83.7	75.7
3150	-----	90.7	87.8	89.5	92.2	94.5	97.0	99.3	100.1	97.8	95.3	90.9	86.5	81.0	72.2
4000	-----	83.2	86.0	88.1	90.4	91.8	93.1	94.3	95.5	93.4	93.2	90.7	85.6	78.1	------
5000	-----	79.5	81.0	83.2	85.8	87.8	87.5	88.1	89.4	88.5	89.7	86.4	81.6	74.3	------
6300	-----	------	------	81.5	81.5	83.1	84.8	87.6	90.0	85.8	86.2	83.9	79.9	------	------
8000	-----	------	------	------	------	82.2	83.6	85.7	88.3	85.4	84.9	------	------	------	------
OASPL	94.3	101.4	104.3	106.6	107.5	108.9	110.4	111.7	113.3	113.9	114.2	114.4	114.2	111.6	107.2

(n) Reduced zone 5 (test 25), downtrimmed NPR

One-third OBCF, Hz	θ, deg														
	20	30	40	50	60	70	80	90	100	110	120	130	140	150	160
	SPL, dB														
50	76.4	83.3	82.0	86.1	91.1	91.3	91.5	92.1	95.2	97.9	100.3	103.7	102.7	101.0	97.2
63	81.8	85.2	85.9	89.6	90.8	91.7	94.2	98.2	99.6	98.9	102.0	105.7	103.6	102.5	95.8
80	80.4	85.7	89.6	88.9	91.0	94.6	96.1	99.1	101.0	101.2	102.3	103.4	101.6	102.6	97.3
100	83.9	85.5	89.3	93.4	94.4	95.3	96.5	97.7	98.0	99.6	101.5	105.8	103.8	103.1	97.4
125	82.7	87.8	92.3	94.7	93.1	95.3	94.3	95.4	96.7	99.4	102.6	104.8	106.1	102.7	97.3
160	84.2	87.9	91.0	93.9	96.2	96.0	96.7	97.8	99.7	101.2	102.1	102.5	103.3	102.2	97.2
200	86.8	90.1	93.0	94.9	95.4	97.3	97.2	98.3	99.7	102.1	101.9	103.8	102.8	101.1	98.4
250	85.3	91.8	93.8	95.6	96.7	97.9	98.0	99.6	101.2	102.7	101.7	103.4	102.7	102.2	97.3
315	86.0	91.4	93.9	95.5	96.5	98.1	98.7	100.4	101.1	103.0	101.8	101.4	101.6	101.2	96.0
400	84.9	90.7	94.6	96.2	96.9	97.6	98.7	100.2	102.1	103.3	102.3	101.9	101.7	100.6	95.8
500	84.4	91.3	94.6	95.9	96.9	98.5	99.5	101.0	102.6	103.4	102.4	101.6	101.9	100.5	94.1
630	82.7	90.7	94.6	96.2	96.5	98.7	99.2	101.2	102.1	103.2	101.4	102.6	101.5	97.8	90.6
800	82.5	90.8	94.0	95.1	97.0	98.6	99.3	100.8	102.3	103.8	101.6	101.4	99.5	95.9	88.8
1000	81.8	91.0	93.7	94.3	96.0	97.1	98.5	99.9	101.3	102.8	101.6	101.0	98.0	93.1	87.4
1250	80.6	90.4	93.2	94.5	95.5	96.2	96.7	98.3	100.3	101.3	100.3	99.8	95.6	91.6	84.2
1600	80.4	89.5	93.2	94.5	95.3	96.7	98.0	99.3	100.8	101.1	98.9	98.6	95.3	89.6	82.6
2000	79.5	88.7	91.6	93.1	94.9	97.4	98.5	99.6	100.9	100.8	98.7	97.3	93.2	87.3	80.5
2500	-----	86.8	90.0	92.5	94.5	96.6	98.4	100.1	101.0	100.7	97.8	95.6	91.8	85.4	77.8
3150	-----	88.7	90.0	90.2	92.4	95.0	97.0	99.1	100.5	99.4	95.9	93.2	88.8	82.8	75.6
4000	-----	84.7	87.1	89.1	91.1	92.1	93.1	94.1	95.2	96.1	94.3	92.9	88.6	80.5	75.0
5000	-----	81.4	81.7	84.1	86.1	87.5	87.8	88.8	89.4	91.5	90.2	89.2	85.4	77.0	74.7
6300	-----	------	------	82.3	82.6	83.1	84.9	87.9	89.8	89.7	87.1	87.0	83.4	------	------
8000	-----	------	------	------	------	82.6	83.6	86.4	88.4	89.0	84.9	------	------	------	------
OASPL	95.6	102.3	105.3	107.0	108.1	109.6	110.5	112.1	113.6	114.6	114.1	115.2	114.3	112.7	107.5

TABLE 7.—Concluded

(o) Adjusted zone 4 (test 26), downtrimmed NPR

One-third OBCF, Hz	θ, deg														
	20	30	40	50	60	70	80	90	100	110	120	130	140	150	160
	SPL, dB														
50	-----	81.2	82.4	85.4	88.5	86.7	86.8	90.8	95.0	97.8	97.8	98.3	99.3	100.5	93.6
63	-----	86.7	88.3	89.2	90.9	90.5	92.4	92.9	96.3	98.9	97.6	101.2	99.4	99.2	93.9
80	76.9	82.9	88.3	89.0	93.0	93.3	94.6	95.6	95.8	95.1	97.5	100.7	102.0	100.1	94.4
100	78.7	84.9	86.4	91.7	92.8	93.2	95.2	94.4	97.7	97.7	100.2	102.0	102.9	100.6	95.7
125	82.0	86.1	90.8	93.0	92.4	94.3	95.9	97.2	98.2	99.8	101.1	102.2	102.8	101.2	96.6
160	81.2	88.6	91.3	93.0	95.8	95.4	97.1	96.7	98.1	101.2	101.6	101.5	100.7	101.6	97.0
200	80.4	89.7	91.5	95.4	95.4	96.6	98.0	97.9	99.4	101.3	101.6	101.1	100.1	100.8	97.0
250	85.4	90.3	92.5	96.1	96.4	97.0	97.4	98.2	98.9	102.1	102.5	99.3	99.6	99.9	96.1
315	85.9	89.7	94.1	96.3	96.5	97.5	97.9	99.2	100.0	101.7	100.8	99.8	100.1	98.7	94.9
400	84.6	90.3	93.9	96.4	97.3	98.0	98.2	99.3	101.0	102.4	101.7	100.9	100.2	98.7	94.3
500	82.3	90.1	94.0	95.5	96.7	97.7	99.3	100.7	100.9	102.5	102.2	101.7	101.0	98.0	91.8
630	81.7	89.1	93.7	95.4	96.7	97.9	99.4	100.5	102.0	101.7	102.1	101.4	100.8	96.5	89.1
800	81.5	90.2	94.0	95.0	96.6	98.1	99.3	100.7	102.5	102.9	102.4	101.6	99.8	94.8	86.9
1000	80.0	89.9	93.5	95.1	96.4	97.4	98.6	100.4	101.6	101.7	101.8	99.6	96.9	92.1	83.3
1250	77.7	90.2	93.3	94.9	96.1	97.0	97.8	99.2	100.7	100.7	101.0	99.5	95.9	90.5	81.6
1600	77.9	89.5	92.8	94.3	95.3	96.4	98.3	99.7	101.2	100.9	100.2	98.2	95.2	89.4	80.9
2000	78.4	89.4	91.2	93.6	95.4	97.1	98.9	100.4	101.6	102.1	99.6	98.2	93.8	88.4	79.1
2500	-----	87.5	90.5	93.2	95.3	97.4	99.1	100.9	102.1	101.6	100.0	96.7	92.9	86.2	77.0
3150	-----	91.6	90.4	91.8	93.5	95.6	98.3	100.9	101.3	100.6	98.1	94.4	90.6	84.0	74.7
4000	-----	87.3	88.2	90.9	92.2	93.7	94.8	95.9	96.8	97.1	97.7	93.8	89.8	83.5	73.9
5000	-----	84.8	83.9	86.3	87.8	89.1	89.3	91.0	92.3	92.8	94.1	90.3	86.5	78.8	------
6300	-----	------	------	85.1	84.6	85.4	86.8	90.2	92.3	90.2	91.1	88.5	85.0	------	------
8000	-----	------	------	------	------	------	86.5	89.3	------	------	------	------	------	------	------
OASPL	93.6	102.0	104.9	107.0	108.2	109.3	110.6	111.3	113.2	114.0	113.8	113.2	112.5	111.0	105.9

Figure 1. F-111 airplane.

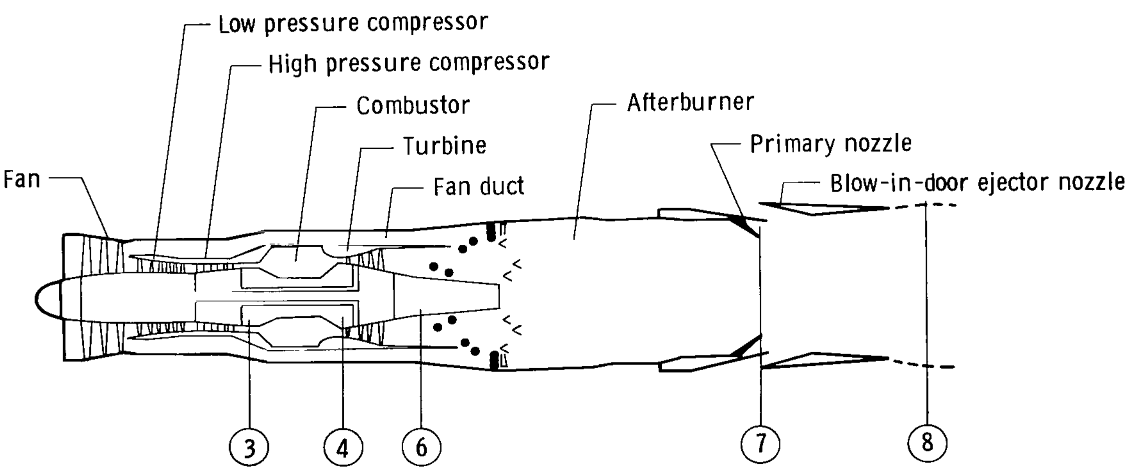


Figure 2. TF30 afterburning turbofan engine and station designations.

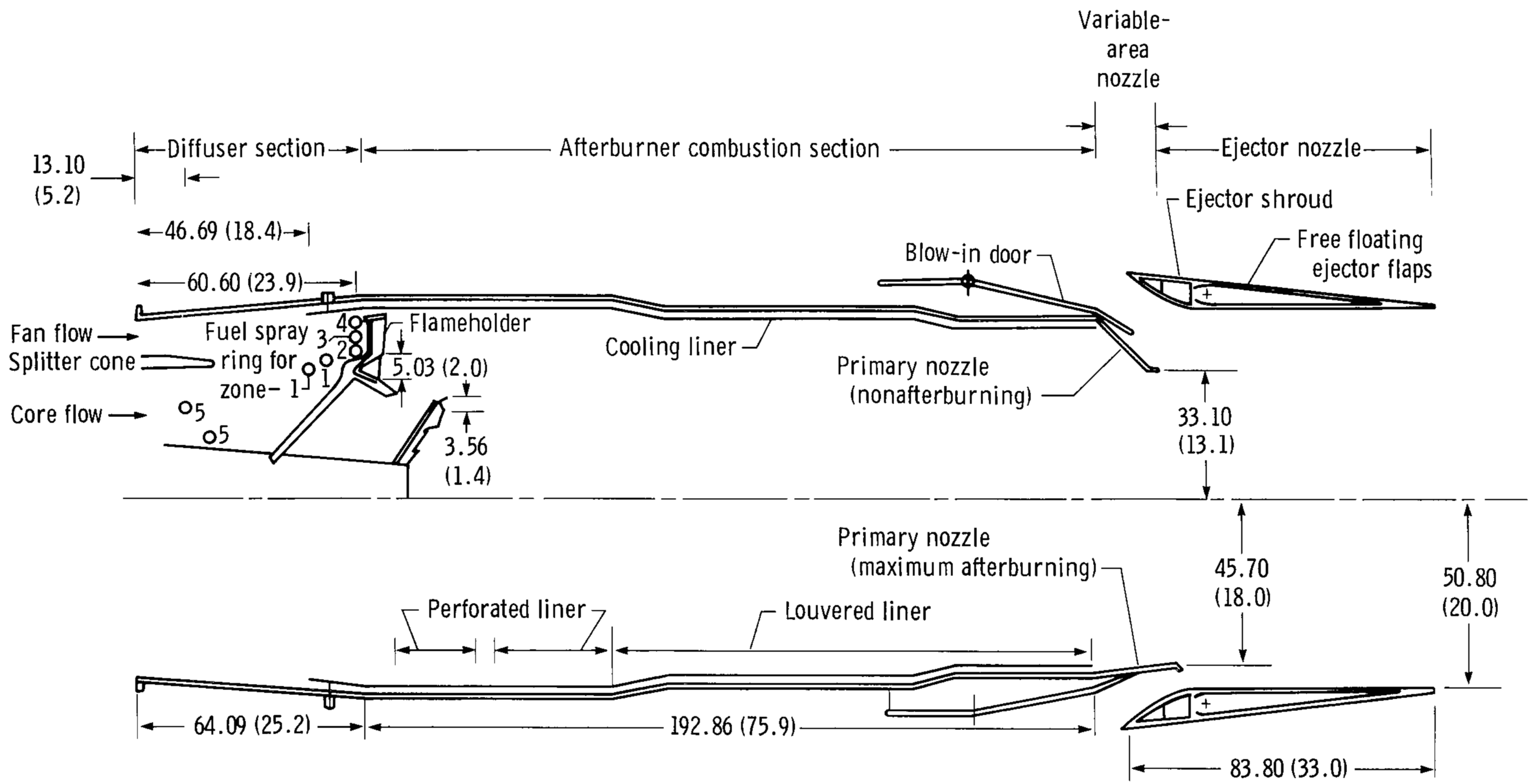


Figure 3. Engine afterburner and nozzle. All dimensions in centimeters (inches).

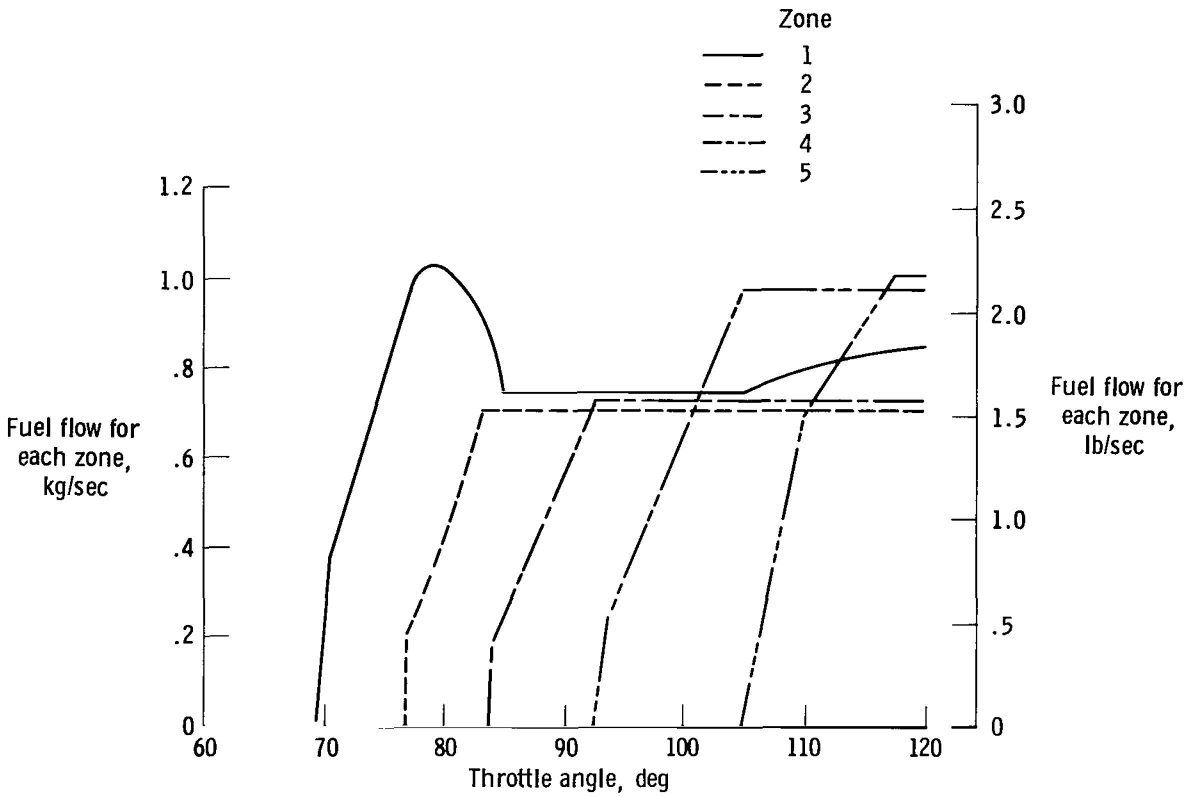


Figure 4. Afterburner zone fuel flow schedule for typical static test.

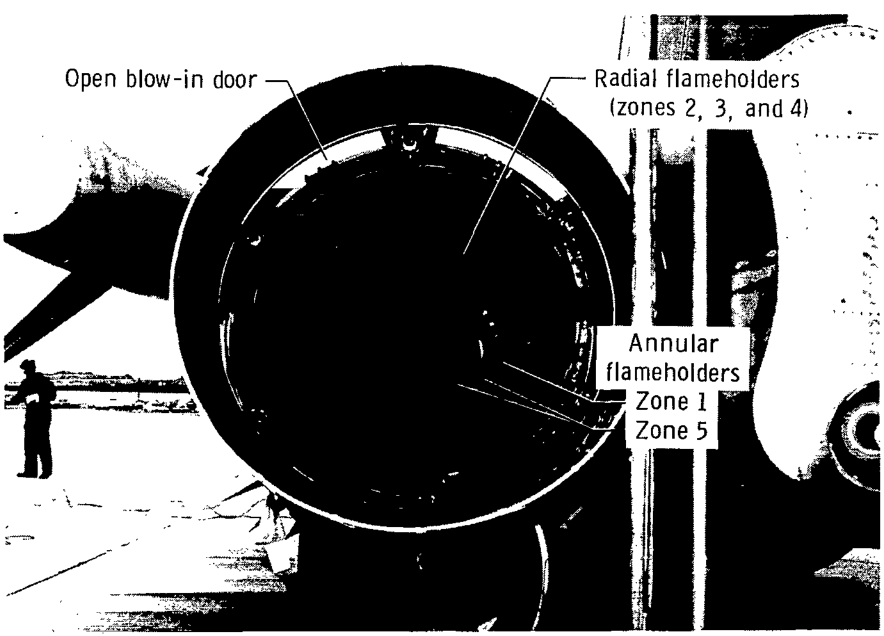


Figure 5. TF30 afterburner and exhaust nozzle.

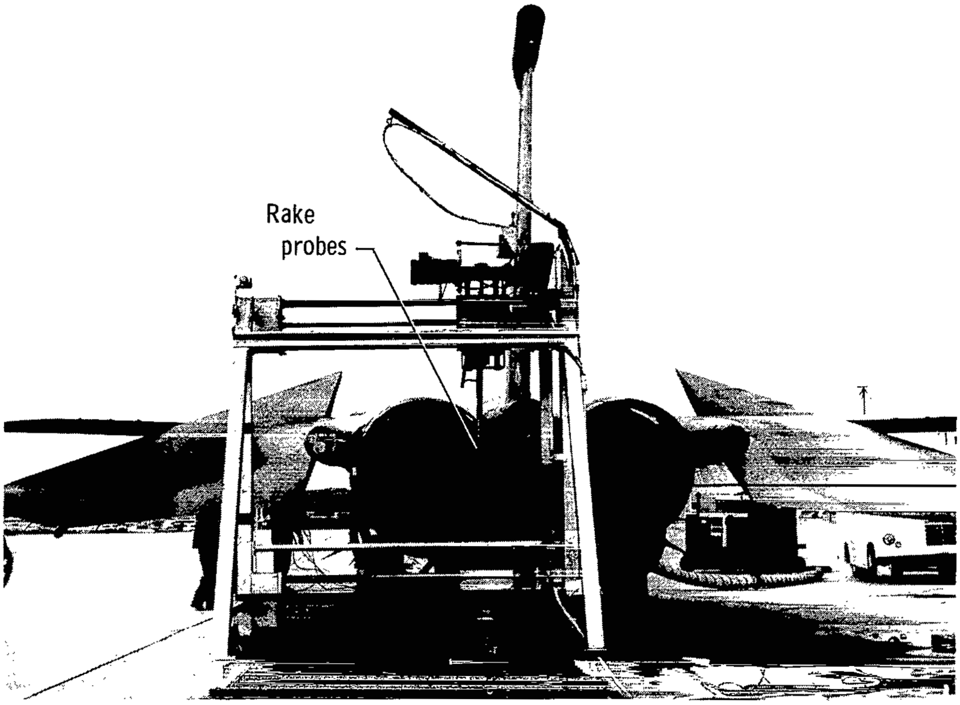


Figure 6. Traversing rake in full inboard position.

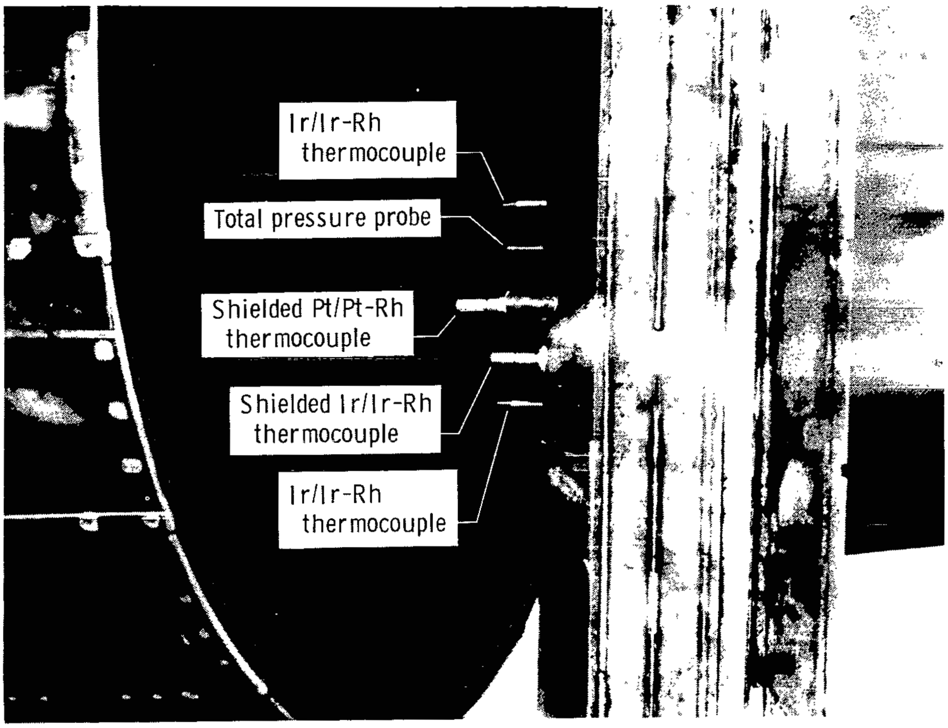


Figure 7. Probes on traversing exhaust survey rake.

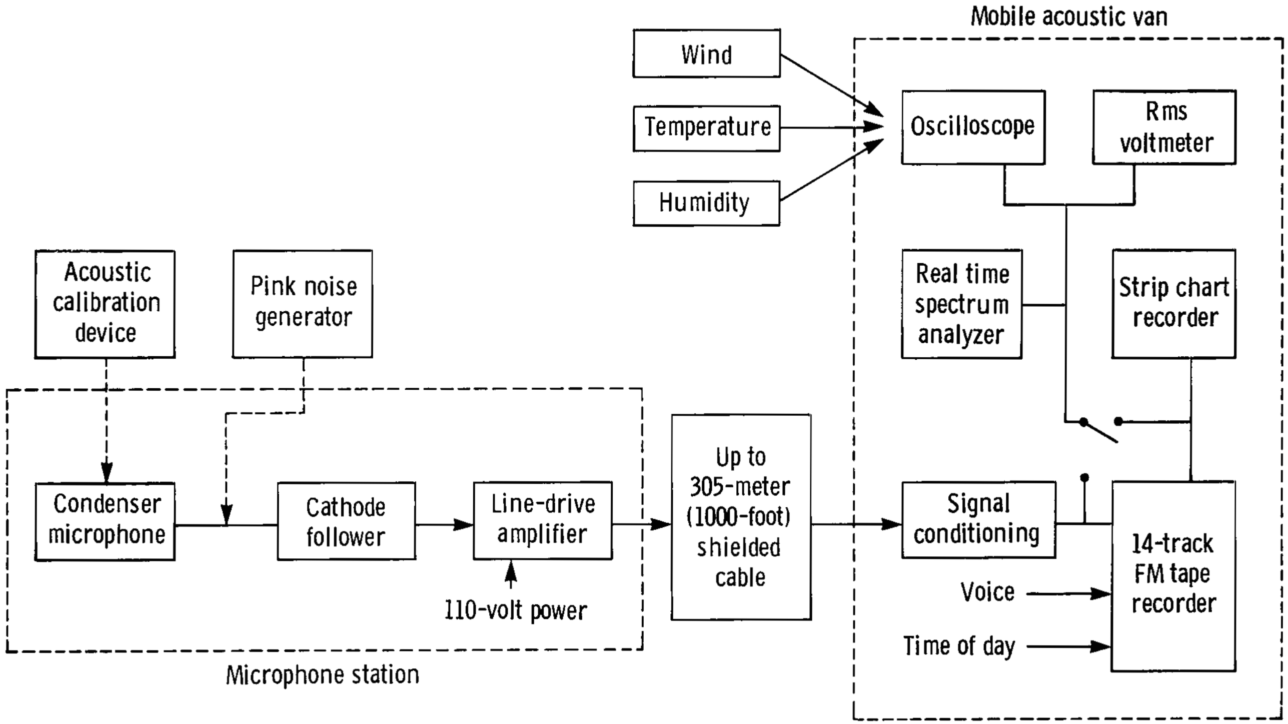


Figure 8. Acoustic data acquisition system.

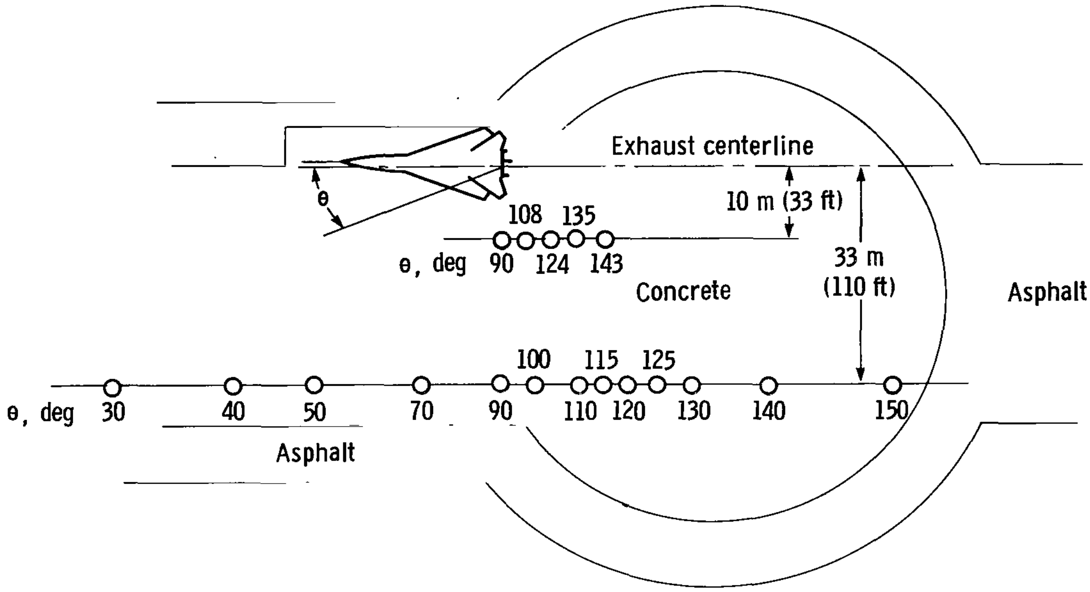


Figure 9. Microphone layout used for static noise survey.

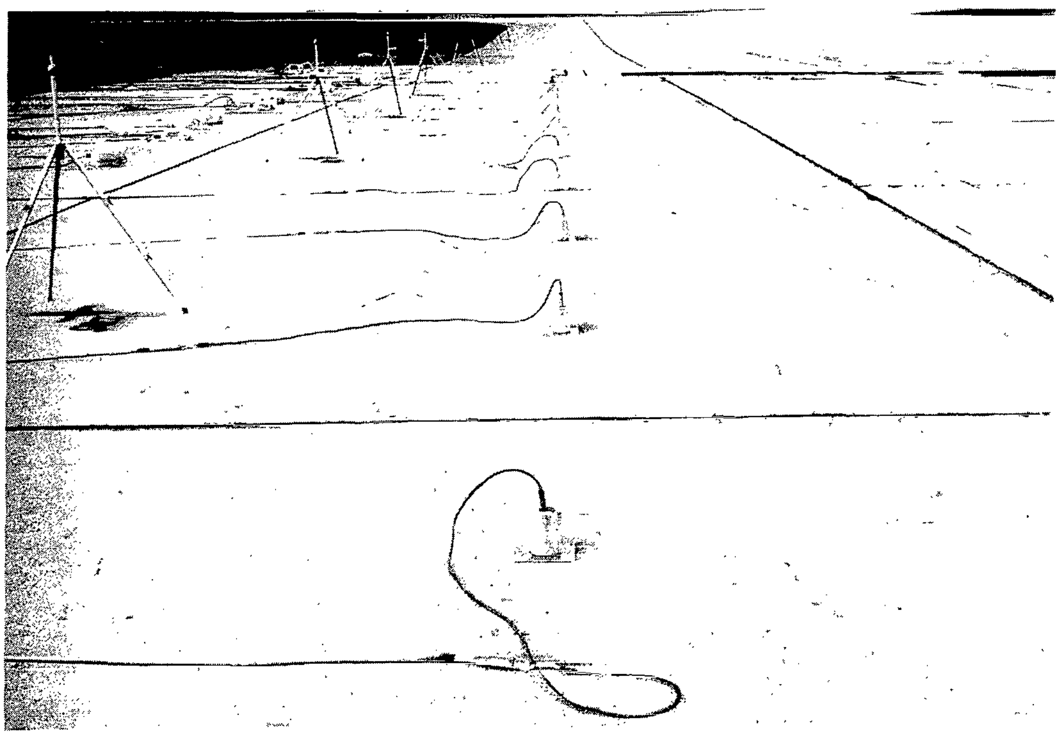


Figure 10. Sideline array of inverted microphones used for static noise survey.

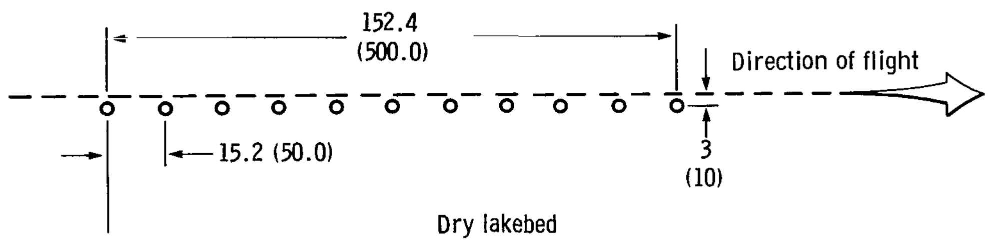


Figure 11. Microphone array used for flyover noise survey. All dimensions in meters (feet).

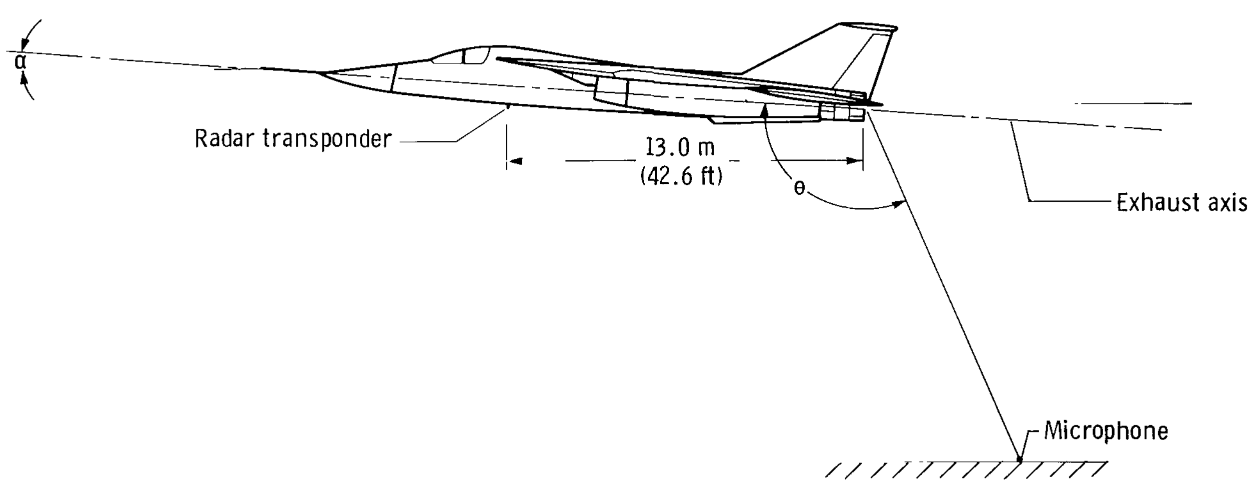
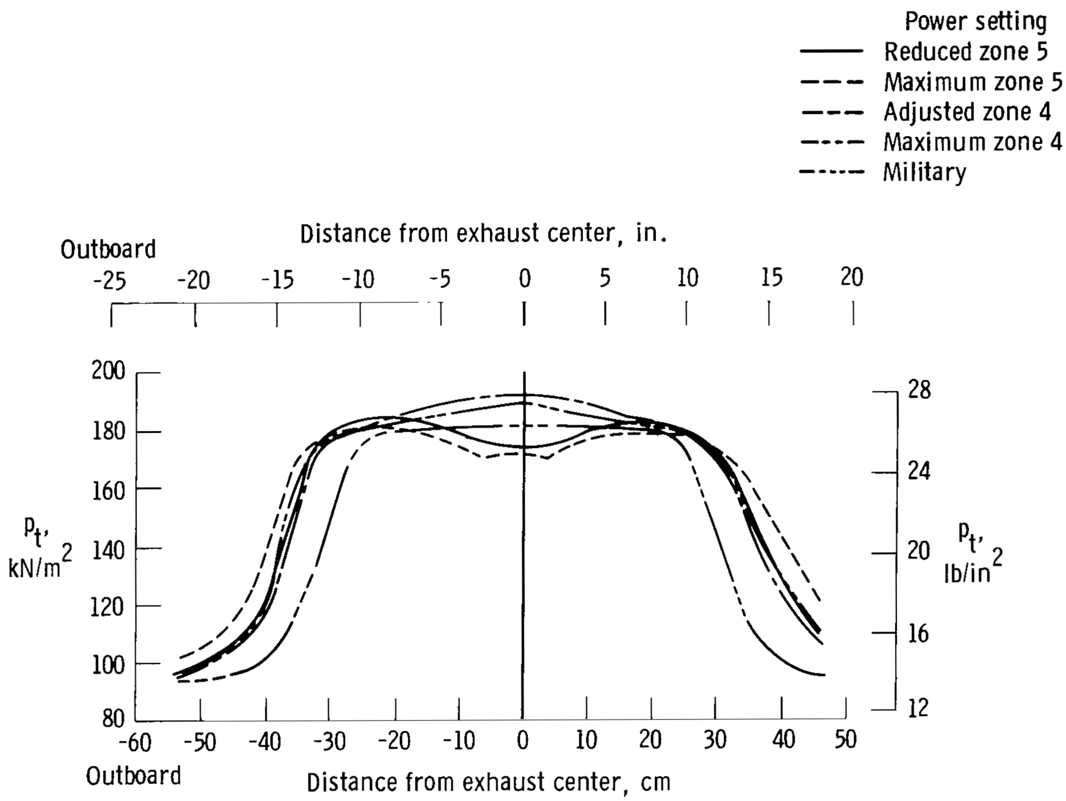
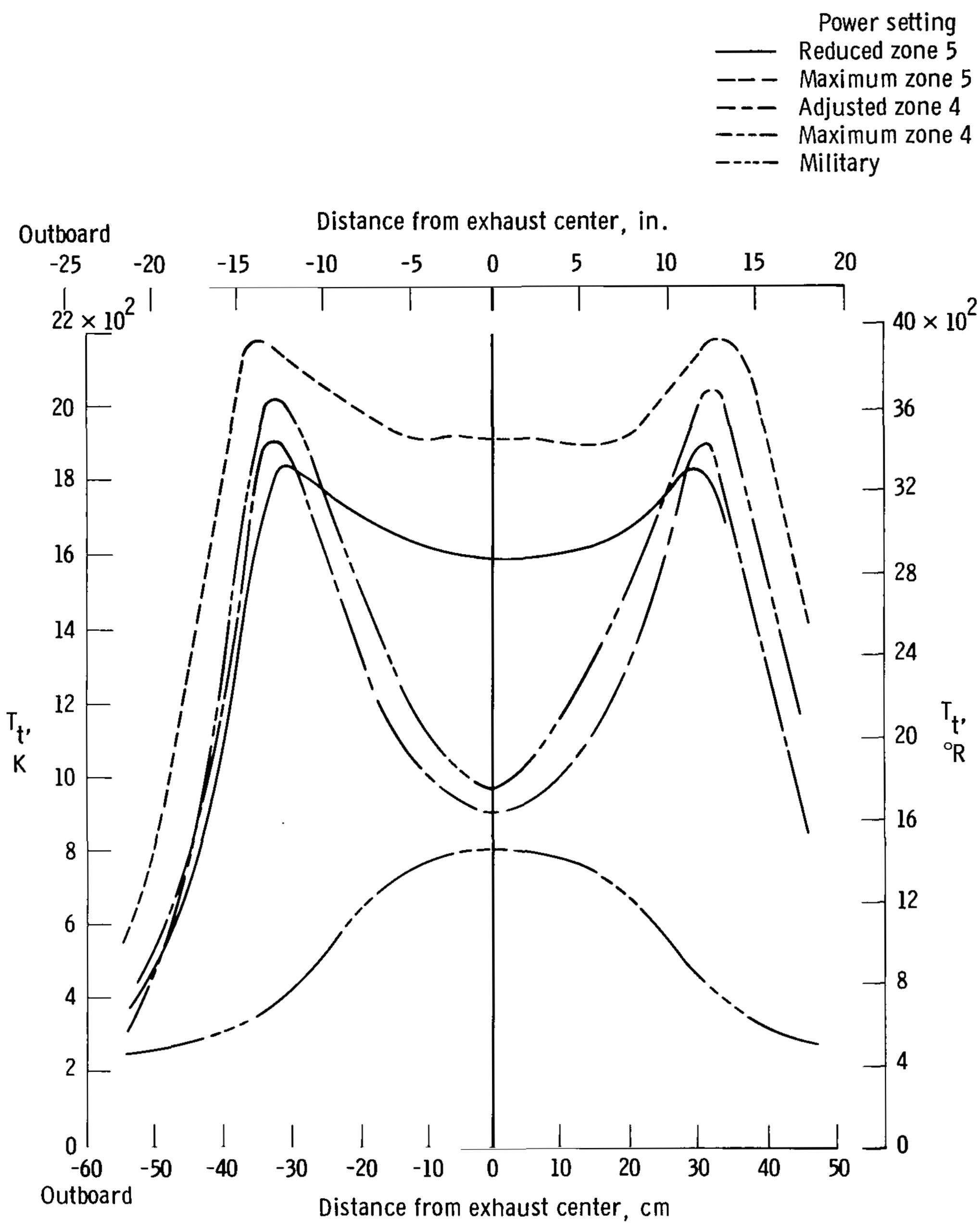


Figure 12. Definition of angles and offset for radar transponder position for flyover noise survey.



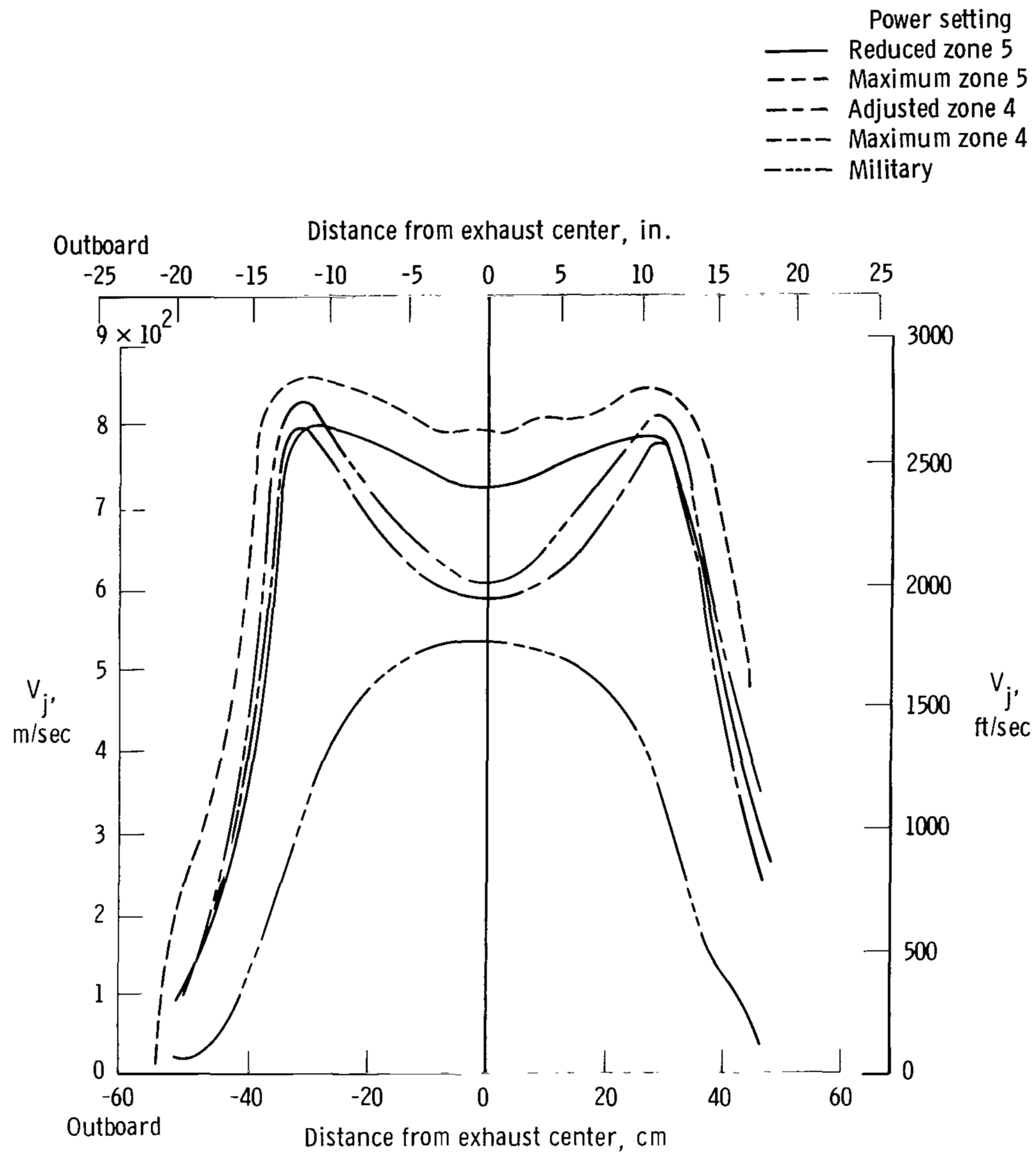
(a) Total pressure.

Figure 13. Exhaust velocity survey flow parameters.



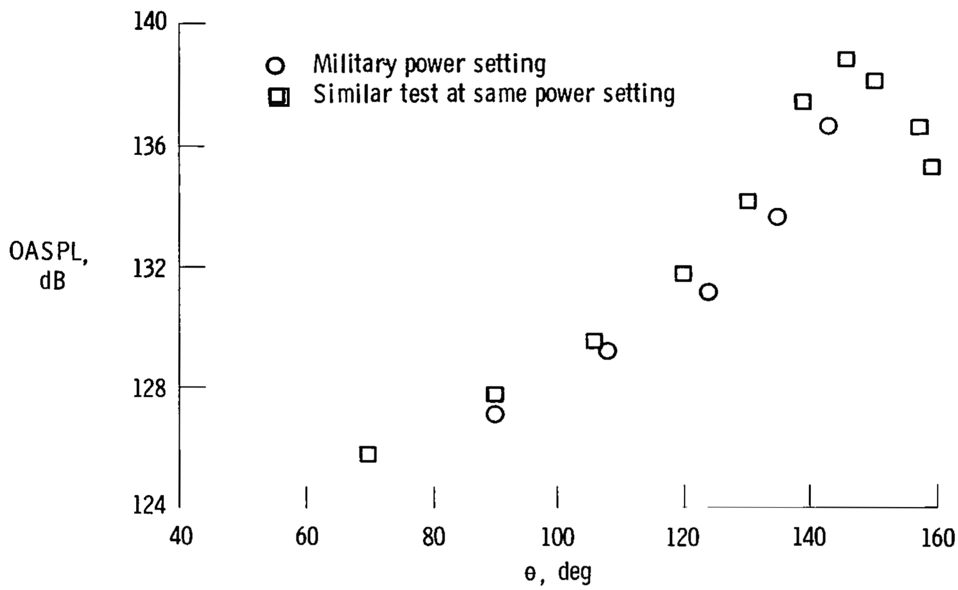
(b) Total temperature.

Figure 13. Continued.

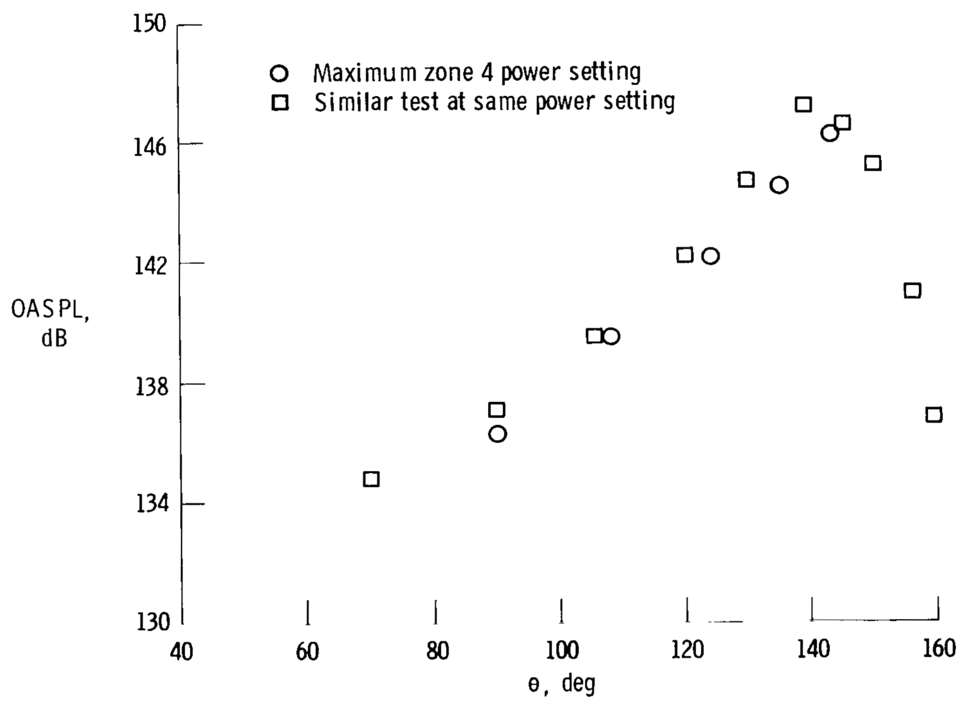


(c) *Velocity.*

Figure 13. Concluded.

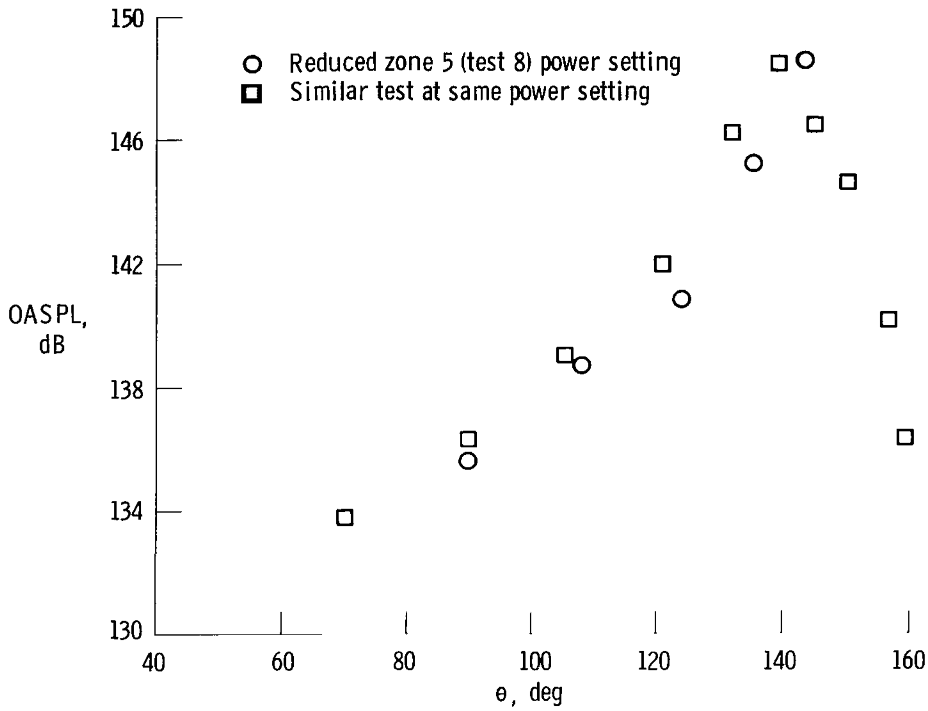


(a) Military power setting.

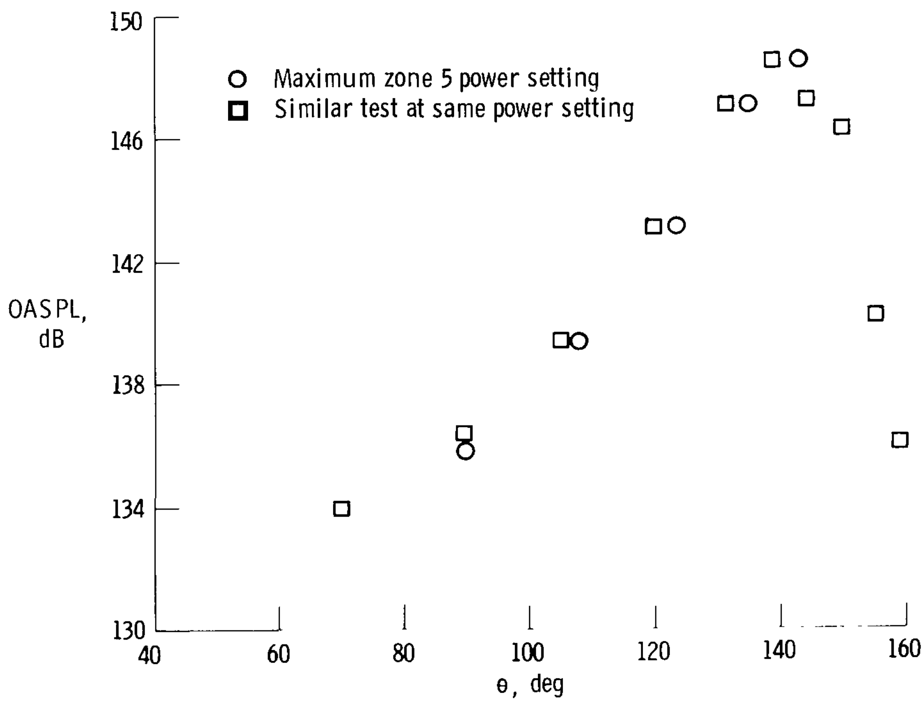


(b) Maximum zone 4 power setting.

Figure 14. Ten-meter (33-foot) sideline static noise.

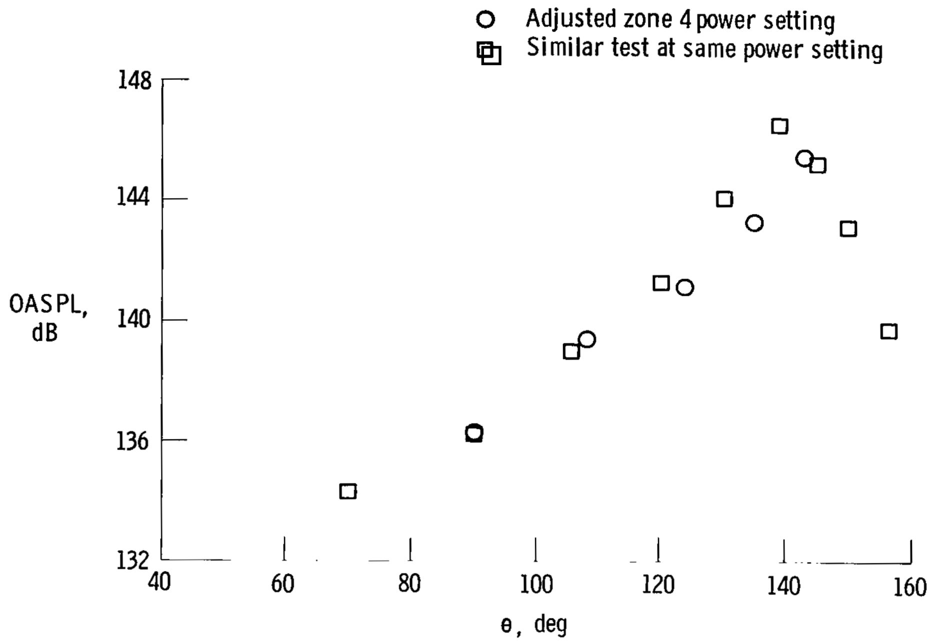


(c) Reduced zone 5 (test 8) power setting.

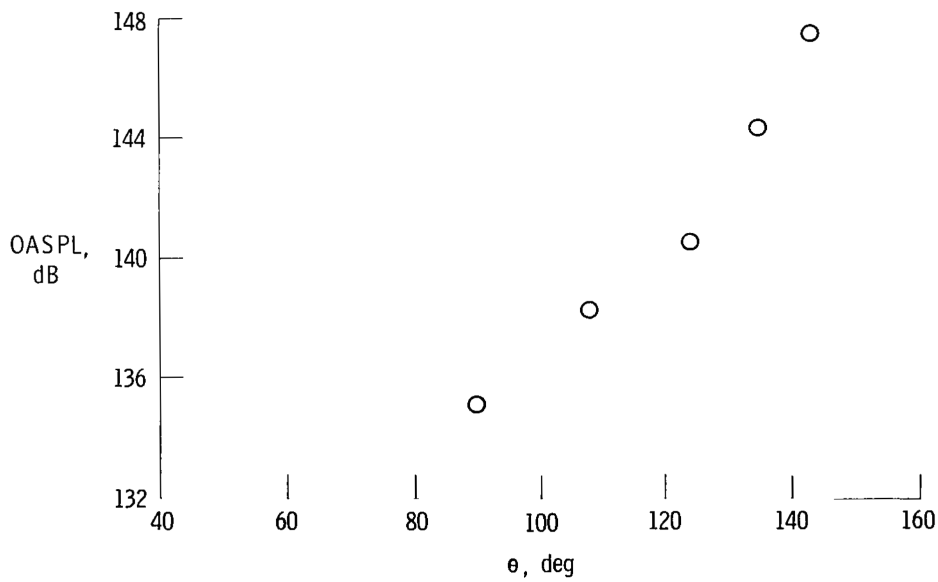


(d) Maximum zone 5 power setting.

Figure 14. Continued.



(e) Adjusted zone 4 power setting.



(f) Reduced zone 5 (test 11) power setting.

Figure 14. Concluded.

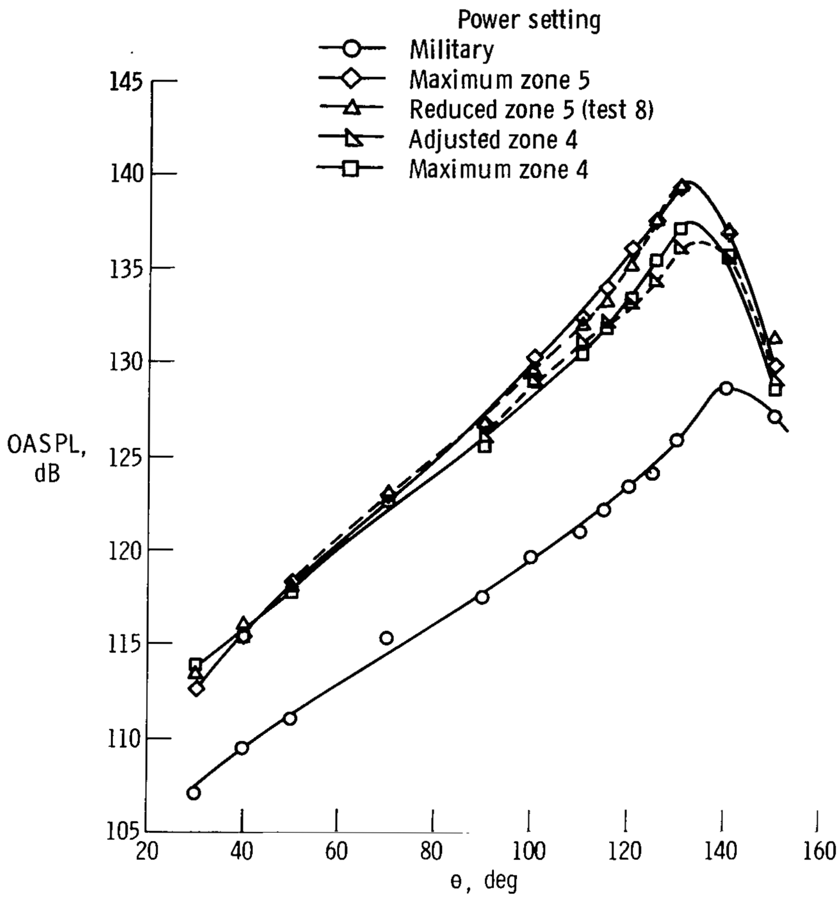
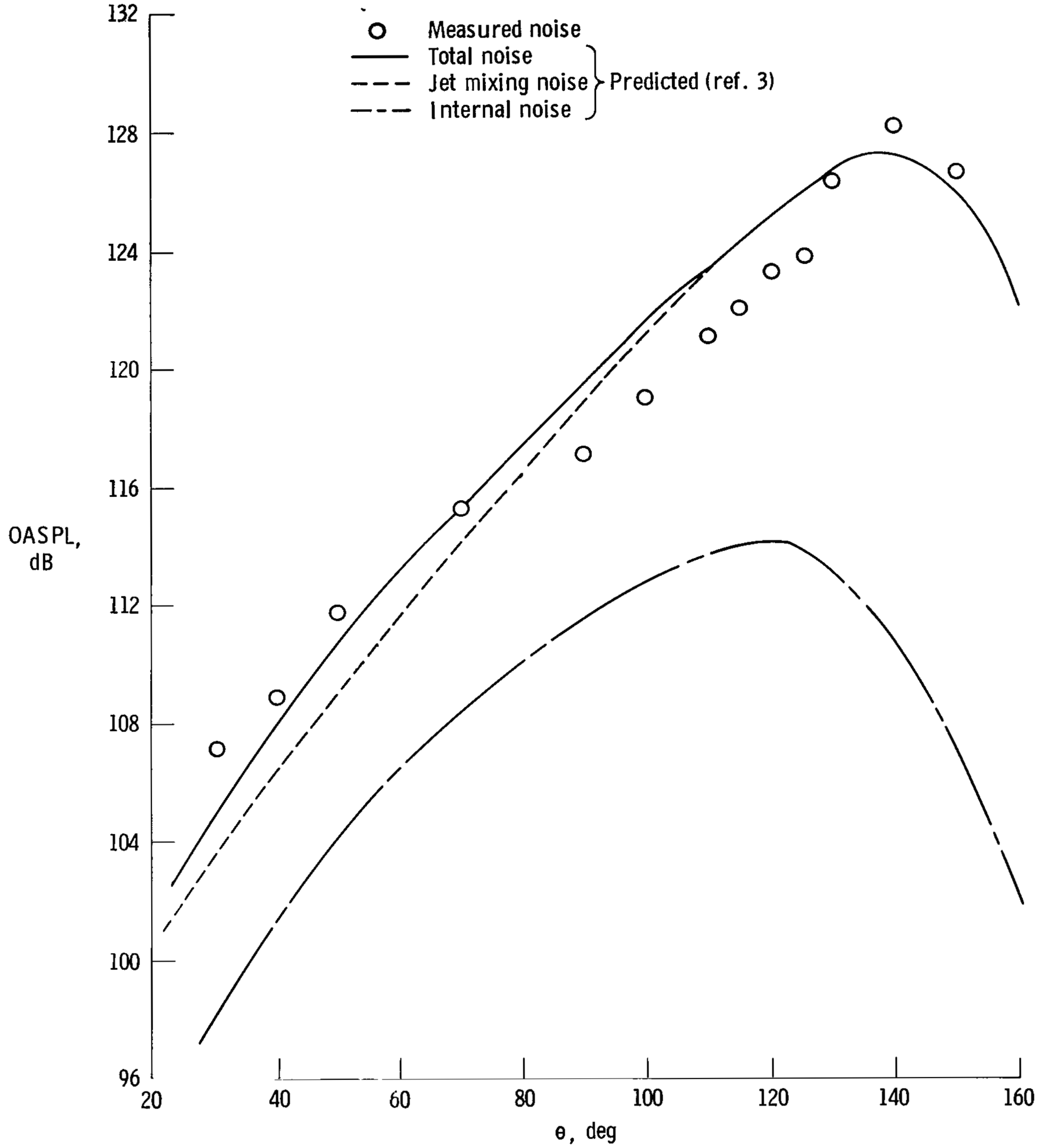
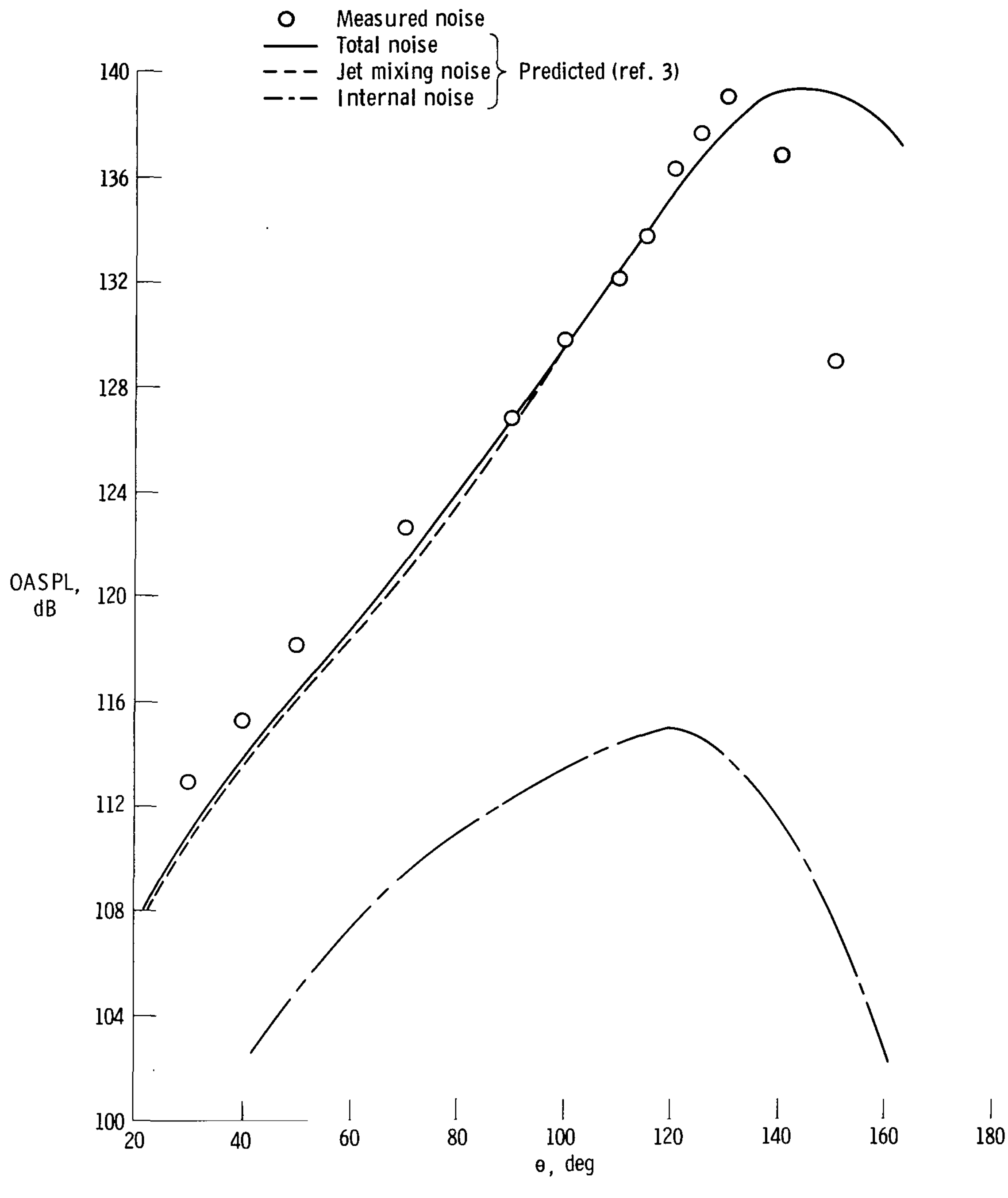


Figure 15. Thirty-three-meter (110-foot) sideline static noise.



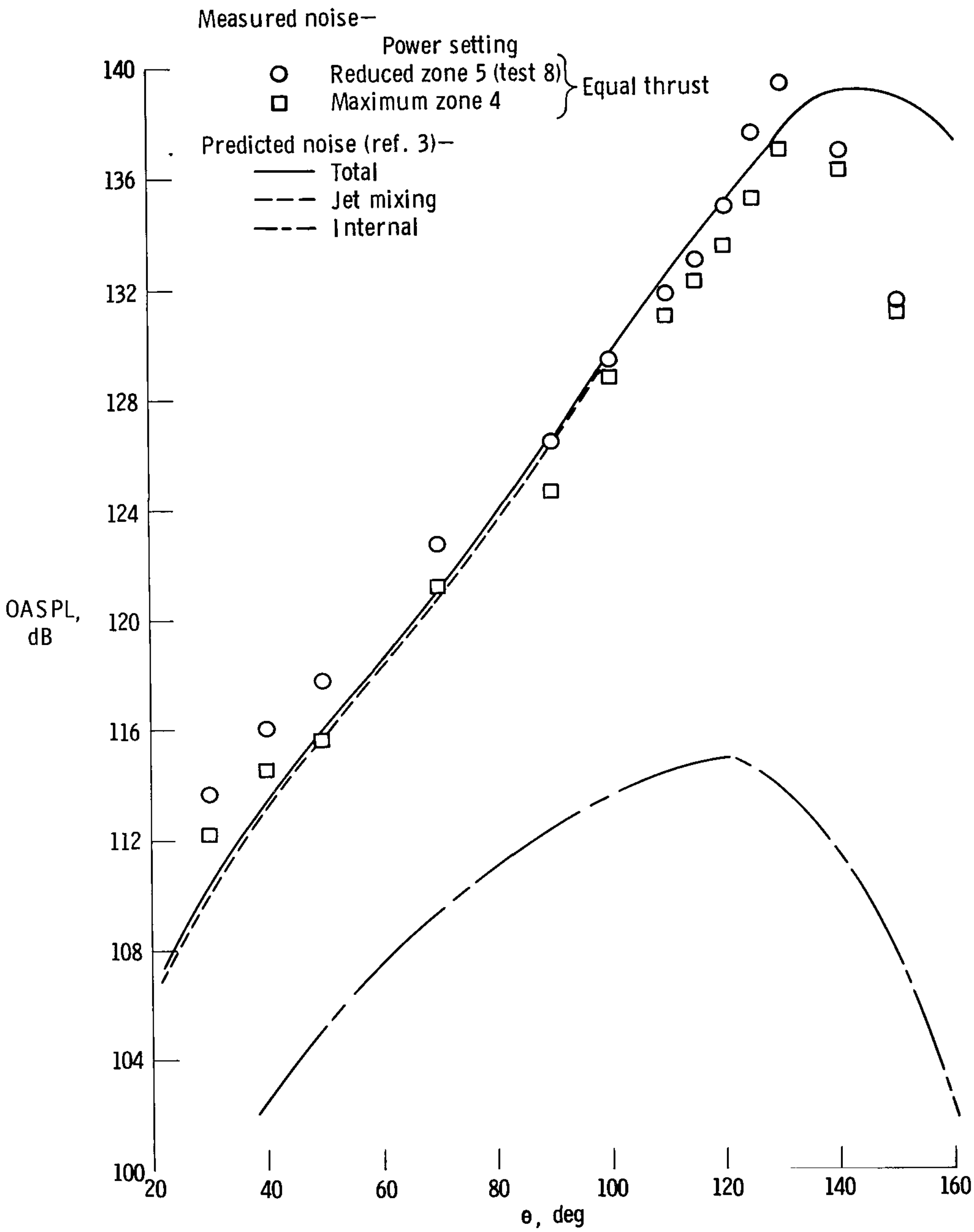
(a) Military power setting.

Figure 16. Comparison of measured with predicted static noise. Thirty-three-meter (110-foot) sideline.



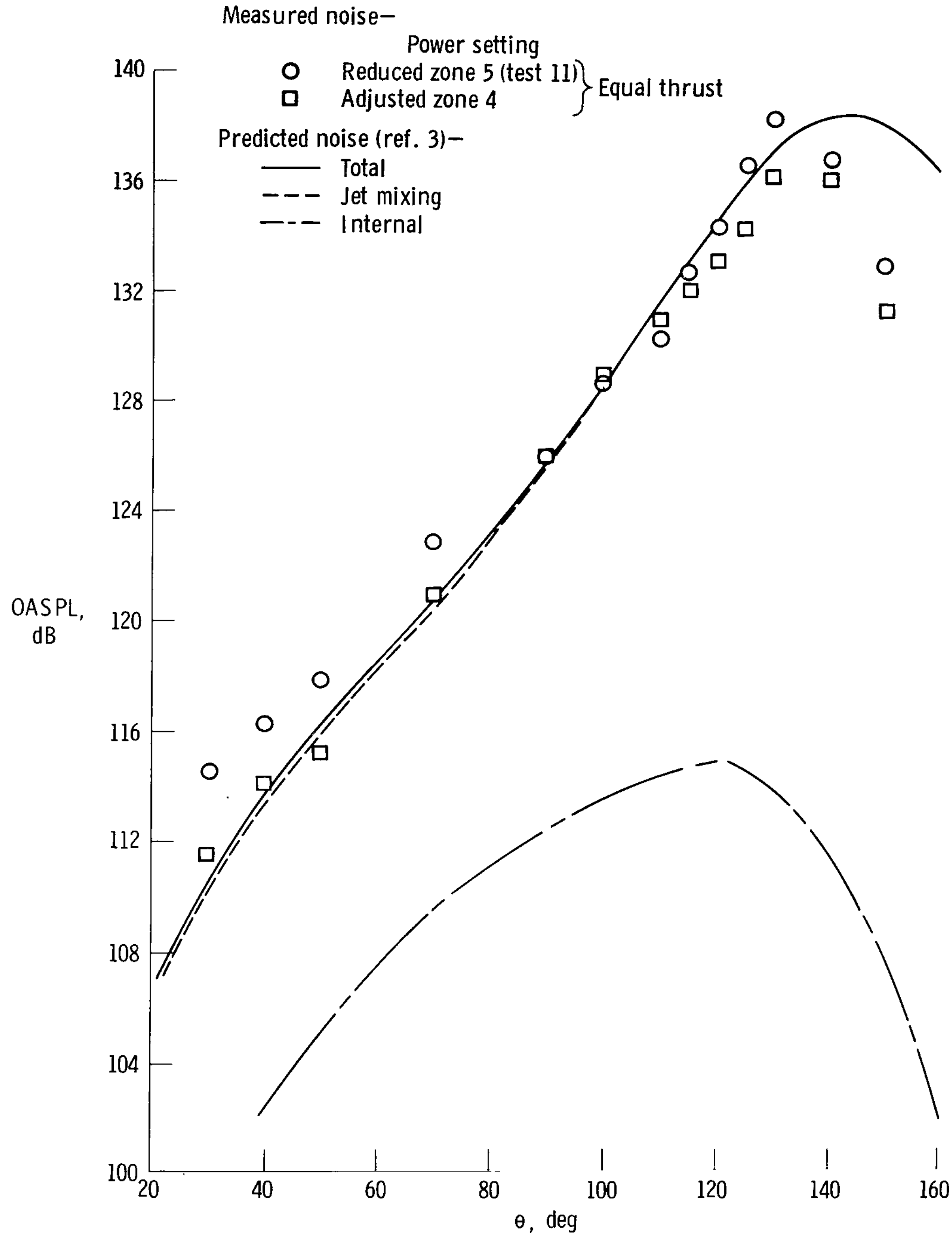
(b) Maximum zone 5 power setting.

Figure 16. Continued.



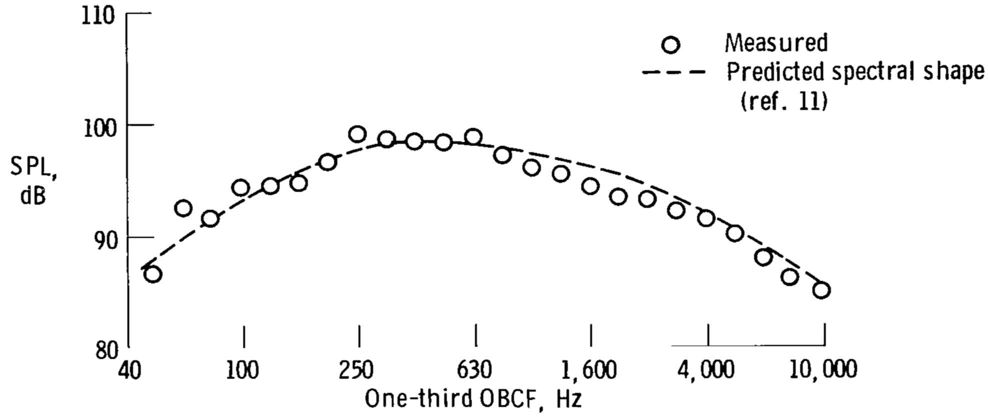
(c) *Reduced zone 5 (test 8) and maximum zone 4 power settings, equal thrust.*

Figure 16. Continued.

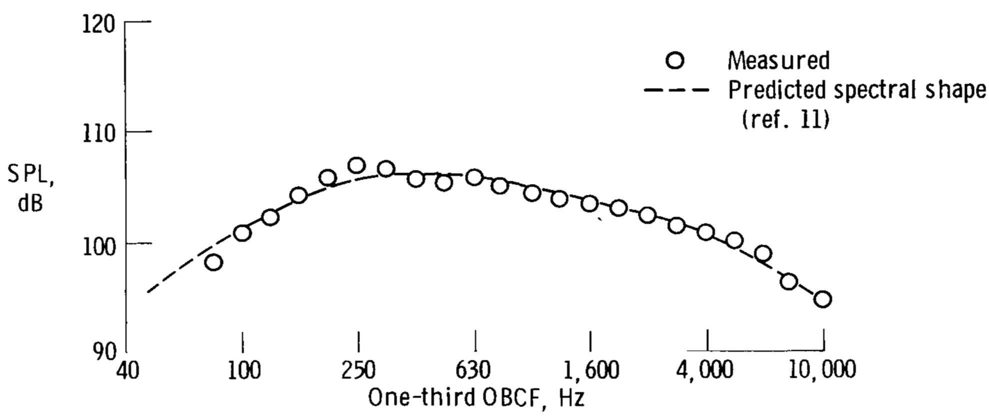


(d) Reduced zone 5 (test 11) and adjusted zone 4 power settings, equal thrust.

Figure 16. Concluded.

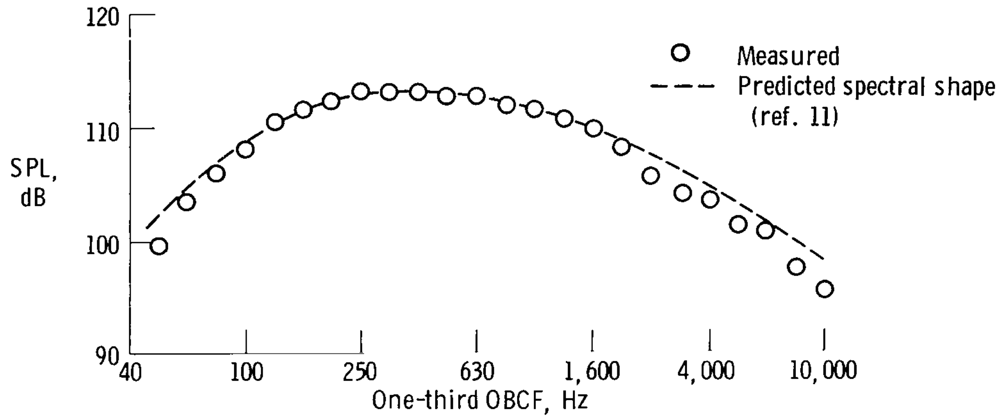


(a) θ = 40°.

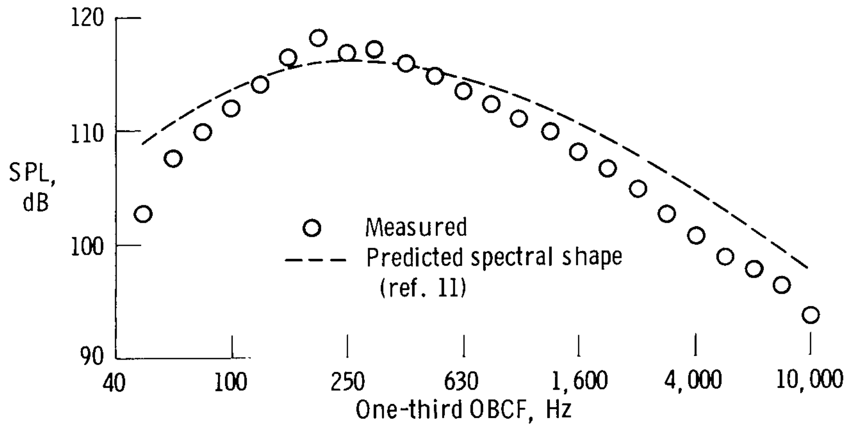


(b) θ = 90°.

Figure 17. Comparison of measured with predicted sound spectra for military power setting at 33-meter (110-foot) sideline.

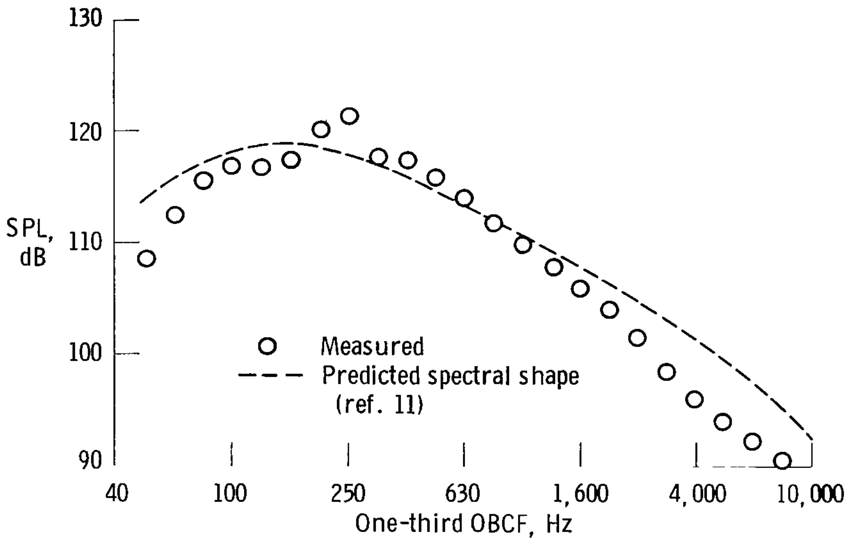


(c) θ = 120°.

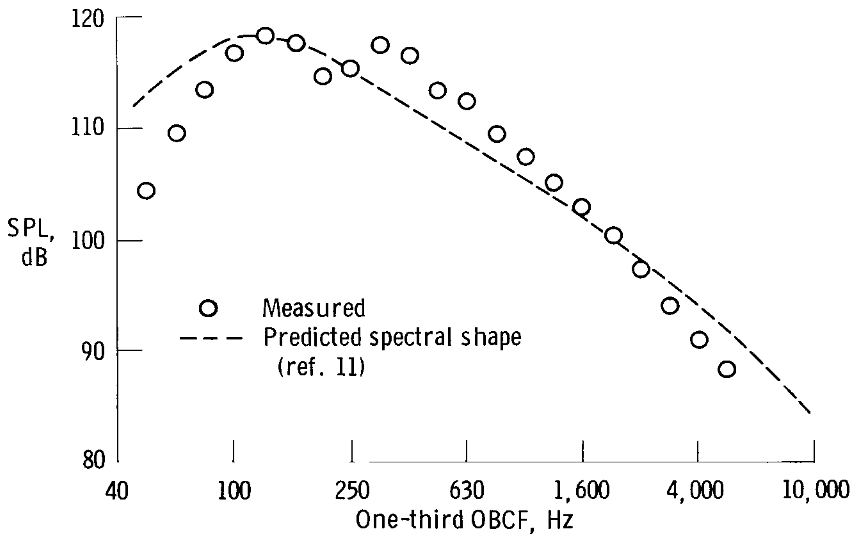


(d) θ = 130°.

Figure 17. Continued.

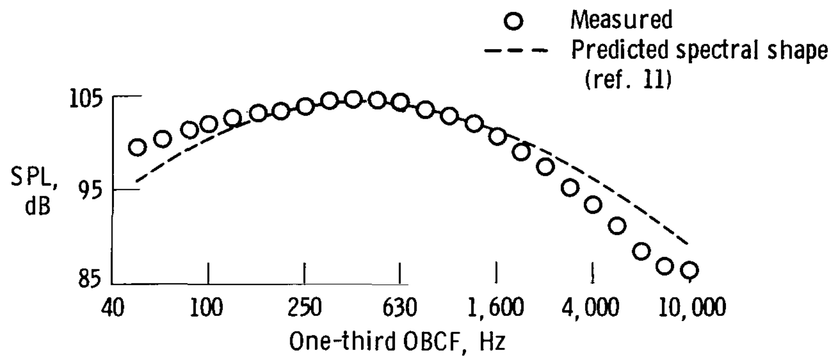


(e) θ = 140°.

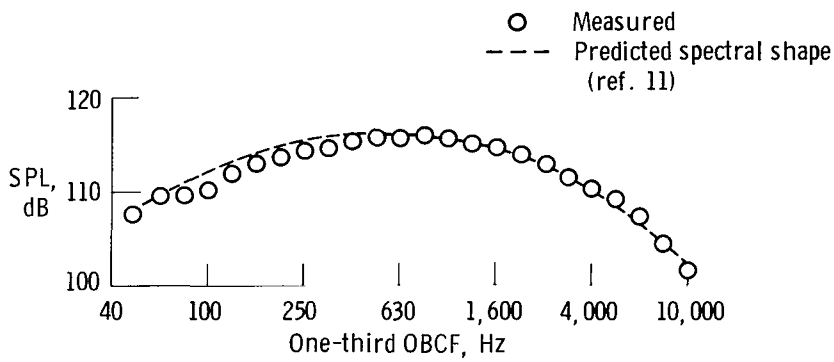


(f) θ = 150°.

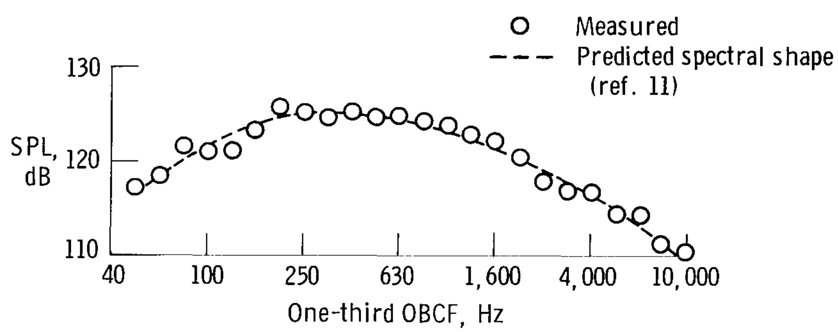
Figure 17. Concluded.



(a) θ = 40°.

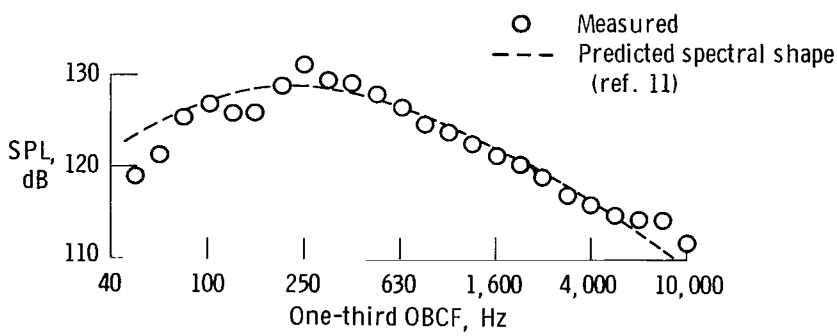


(b) θ = 90°.

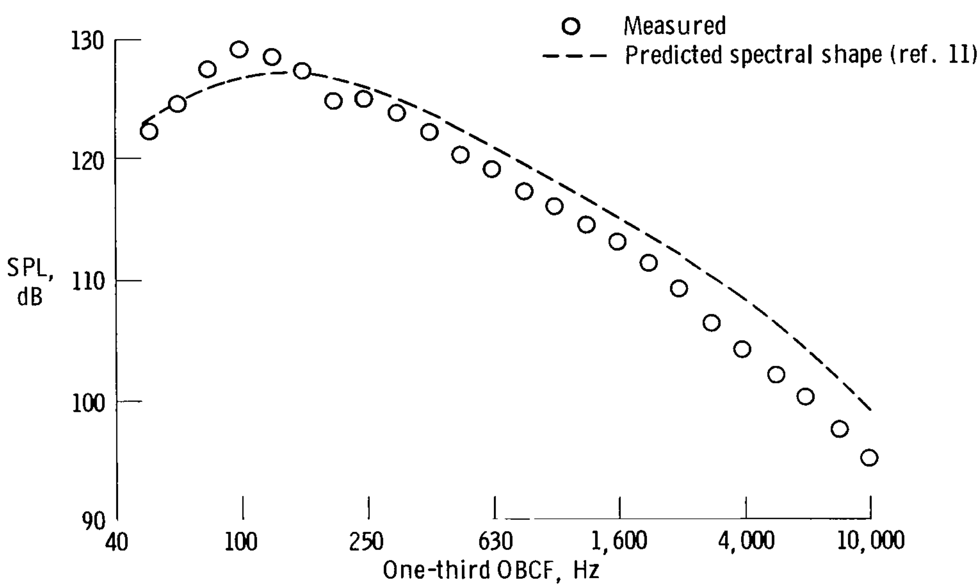


(c) θ = 120°.

Figure 18. Comparison of measured with predicted sound spectra for maximum zone 5 power setting. Afterburning; 33-meter (110-foot) sideline.

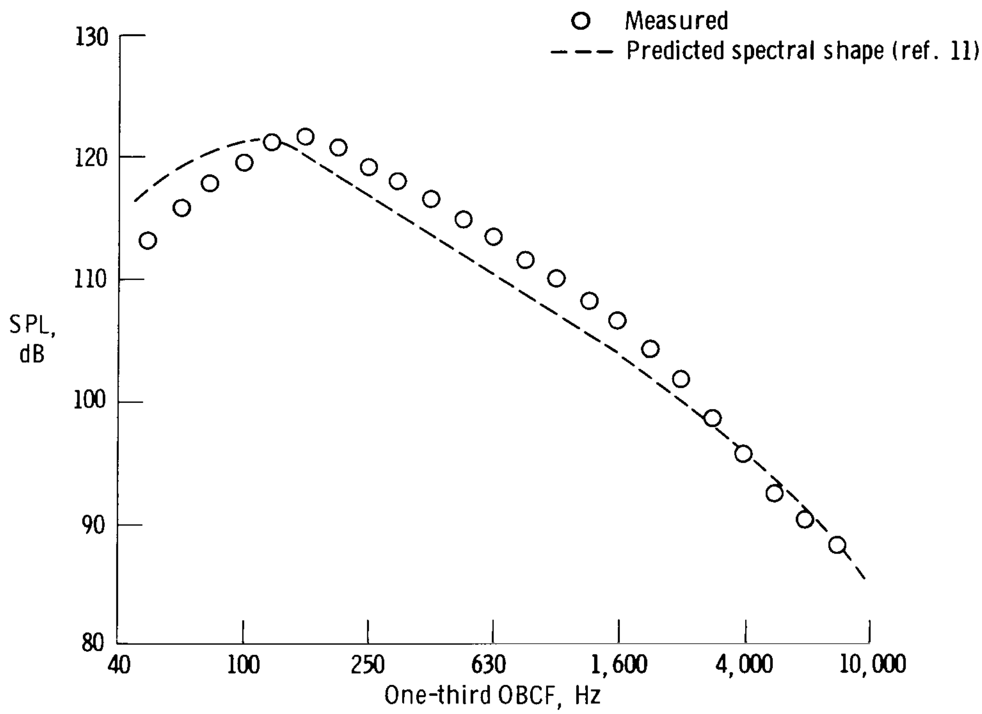


(d) θ = 130°.



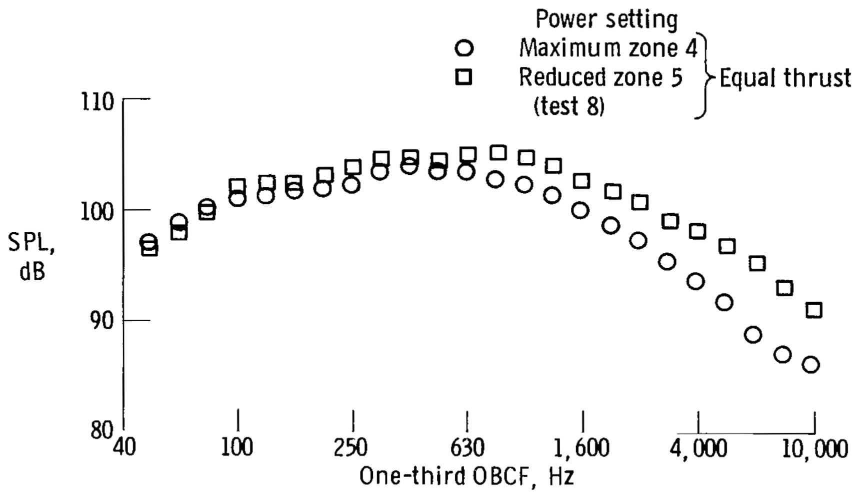
(e) θ = 140°.

Figure 18. Continued.

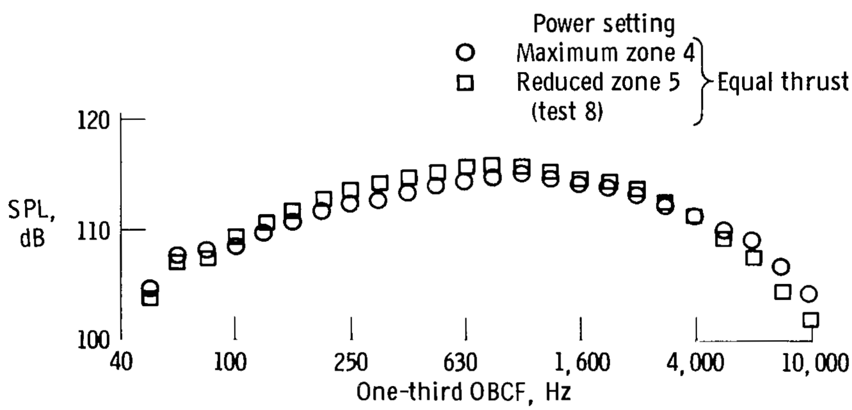


(f) $\theta = 150°$.

Figure 18. Concluded.

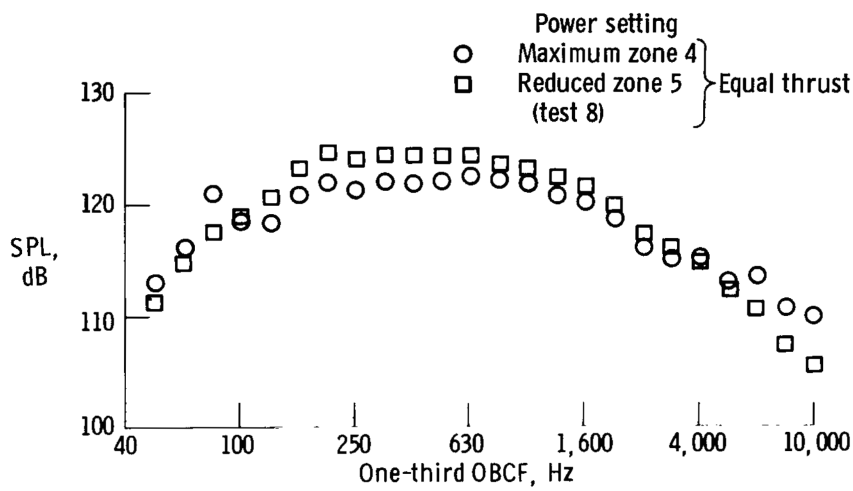


(a) θ = 40°.

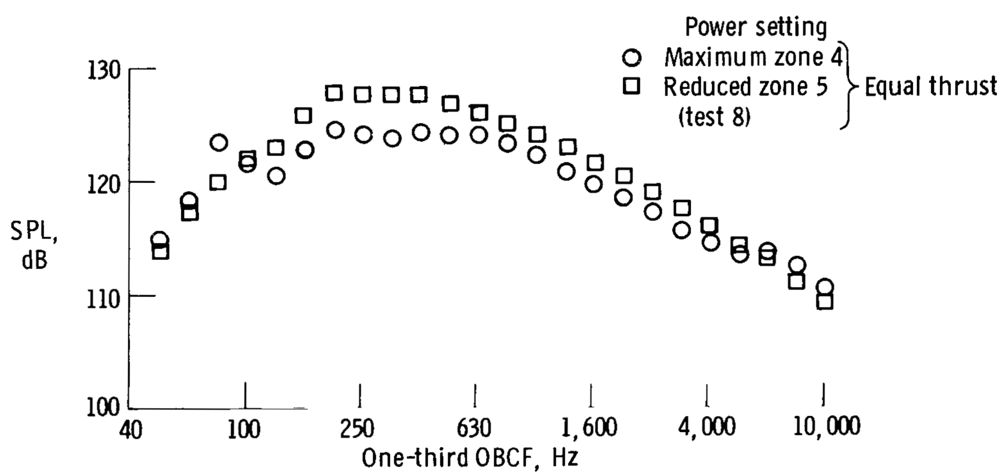


(b) θ = 90°.

Figure 19. Comparison of sound spectra for equal thrust maximum zone 4 and reduced zone 5 (test 8) power settings. Thirty-three-meter (110-foot) sideline.

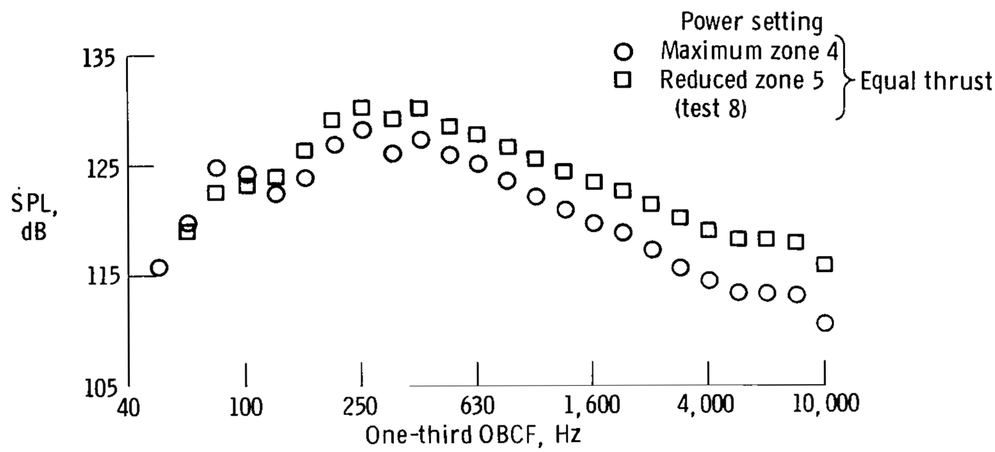


(c) θ = 120°.

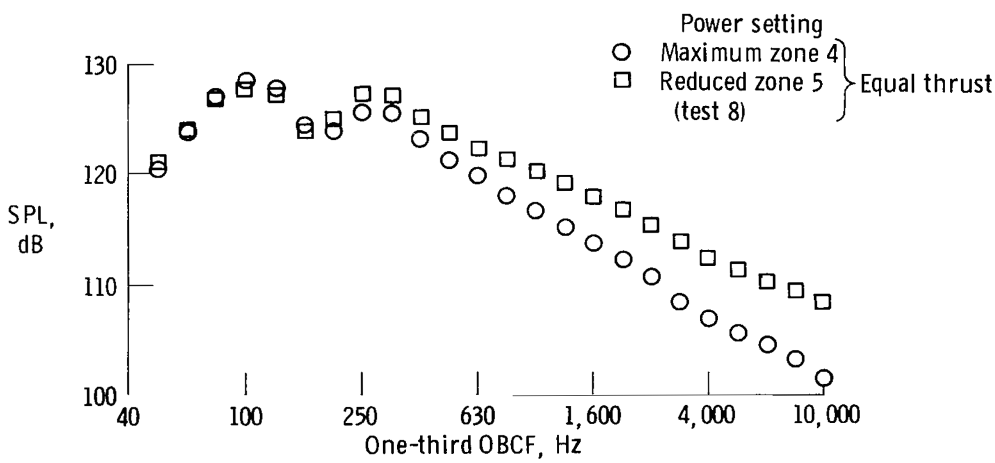


(d) θ = 125°.

Figure 19. Continued.



(e) $\theta = 130°$.



(f) $\theta = 140°$.

Figure 19. Concluded.

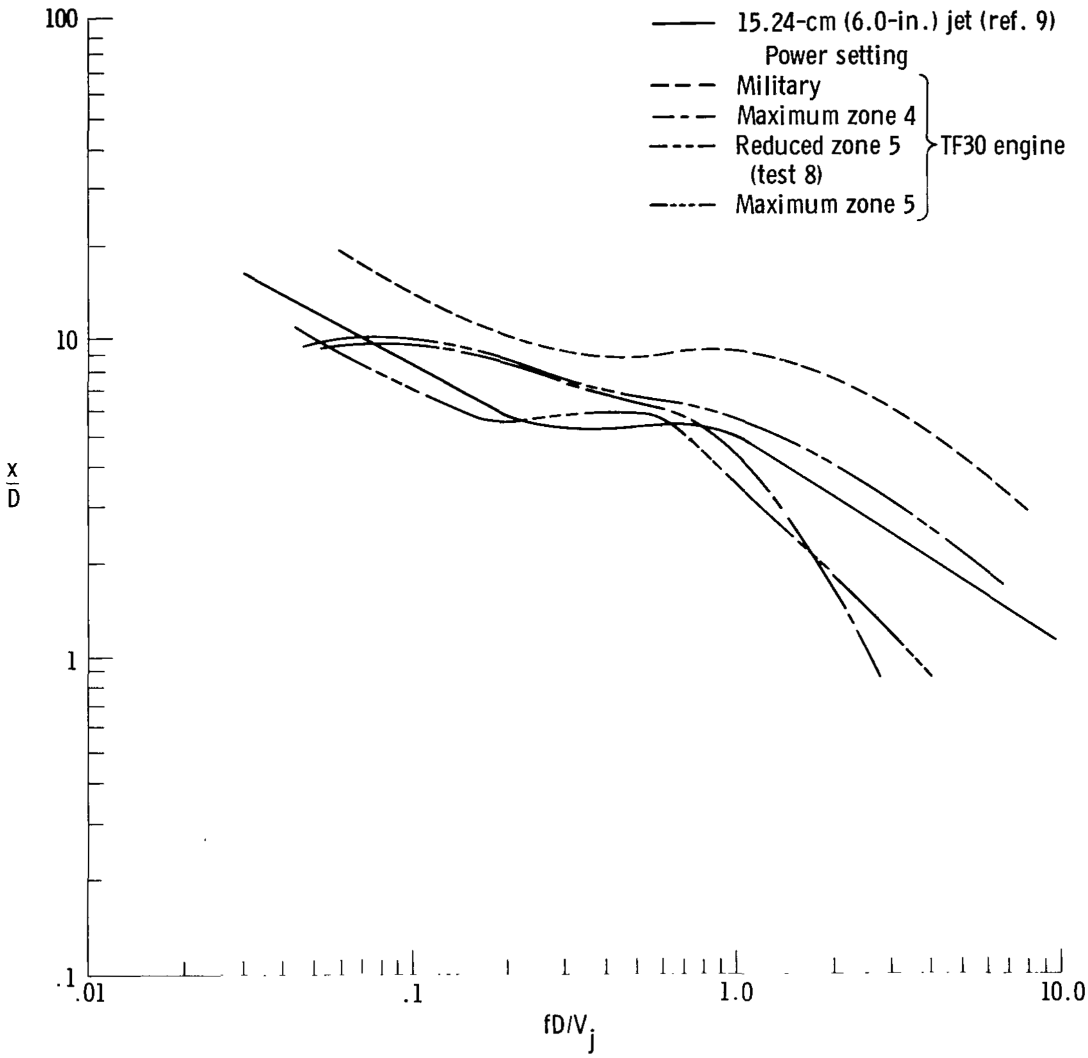


Figure 20. Measured noise sources for TF30 engine and hot jet model.

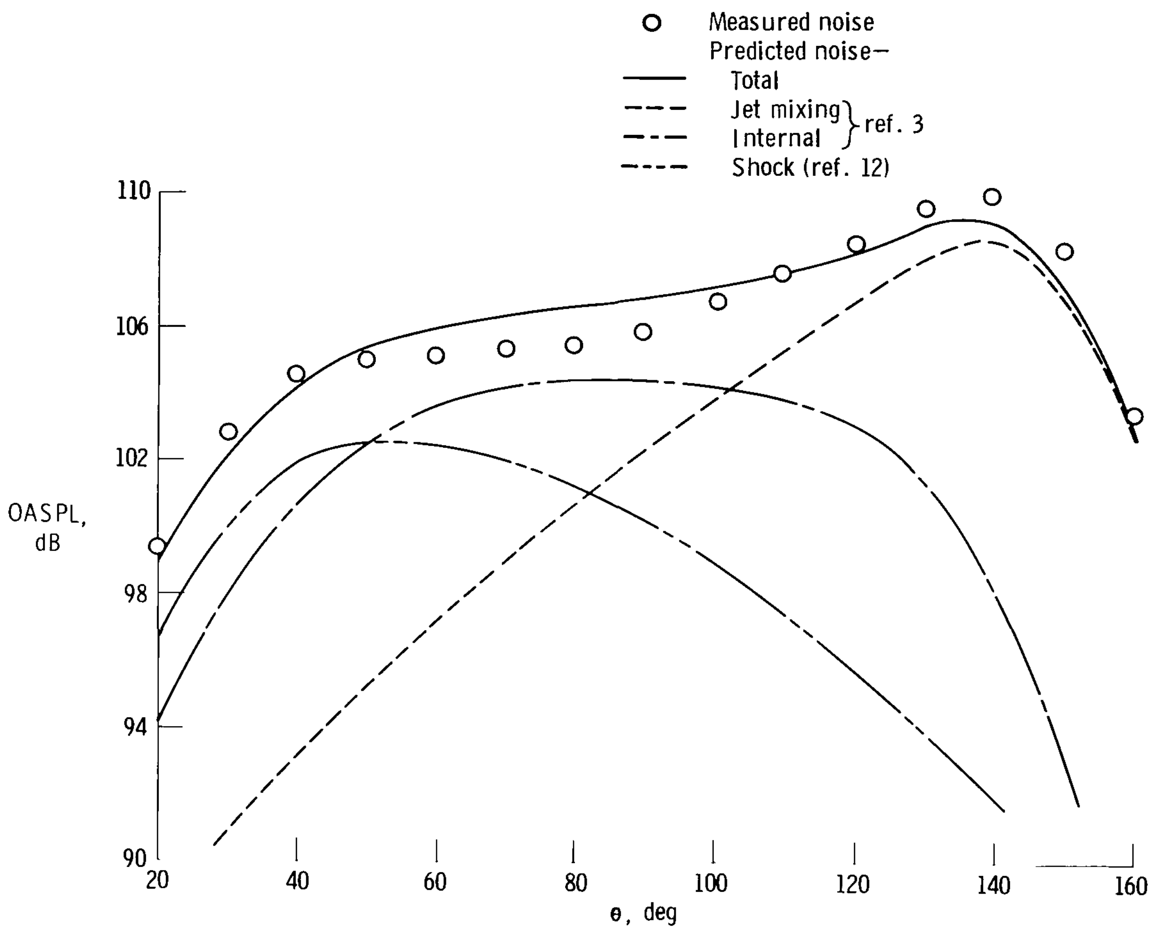
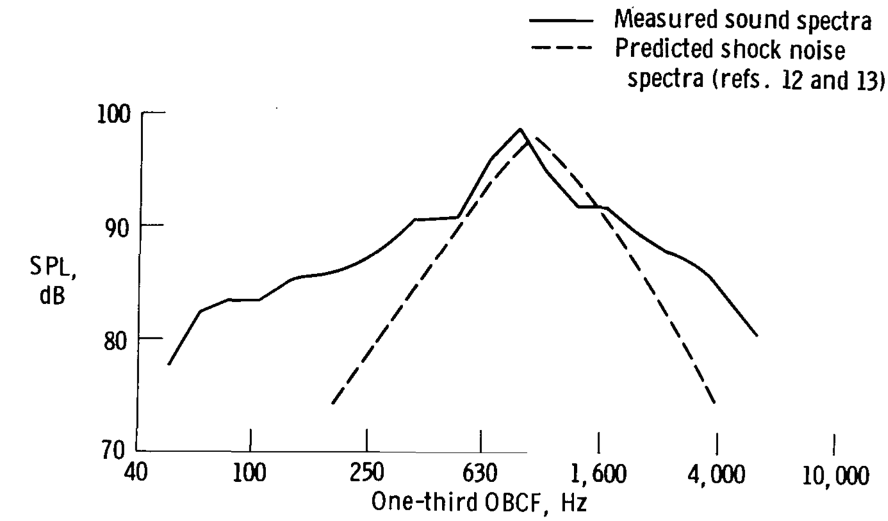
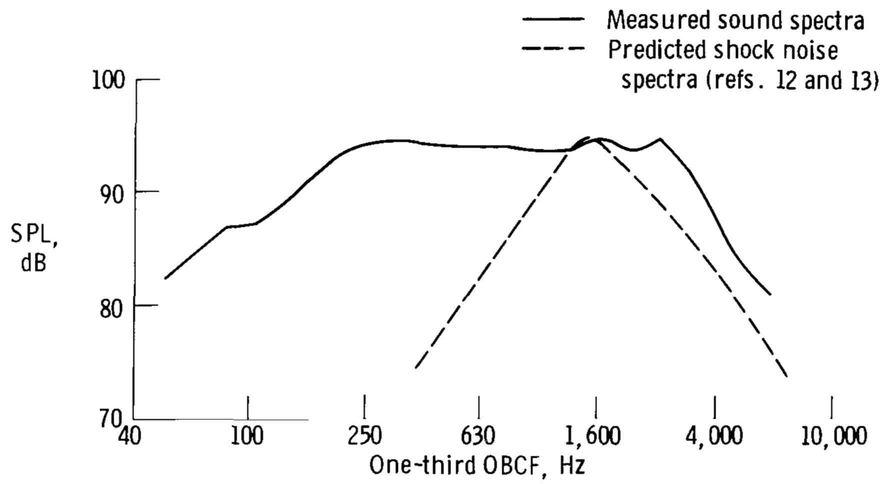


Figure 21. Comparison of measured with predicted flyover noise for military power (test 12) power setting. Supersonic exhaust; 152-meter (500-foot) flyover.

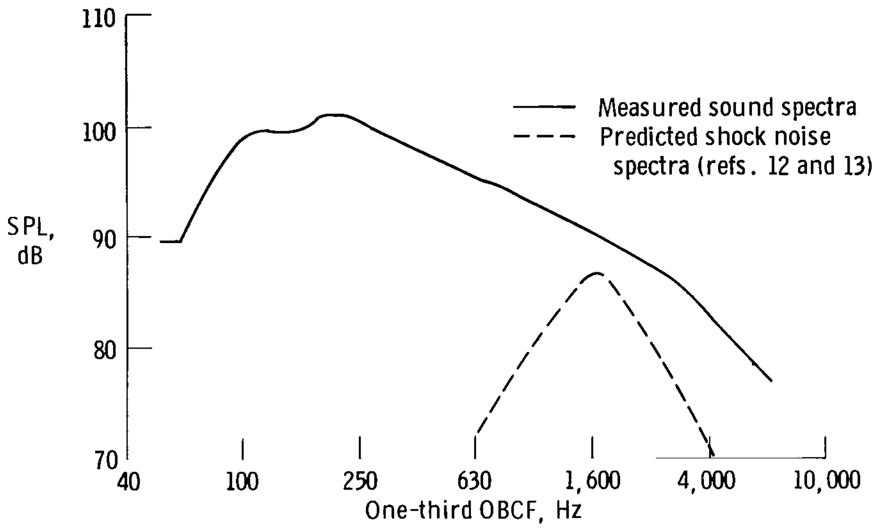


(a) $\theta = 40°$.



(b) $\theta = 90°$.

Figure 22. Comparison of measured with predicted sound spectra for military power (test 12) power setting. Supersonic exhaust; 152-meter (500-foot) flyover.



(c) θ = 130°.

Figure 22. Concluded.

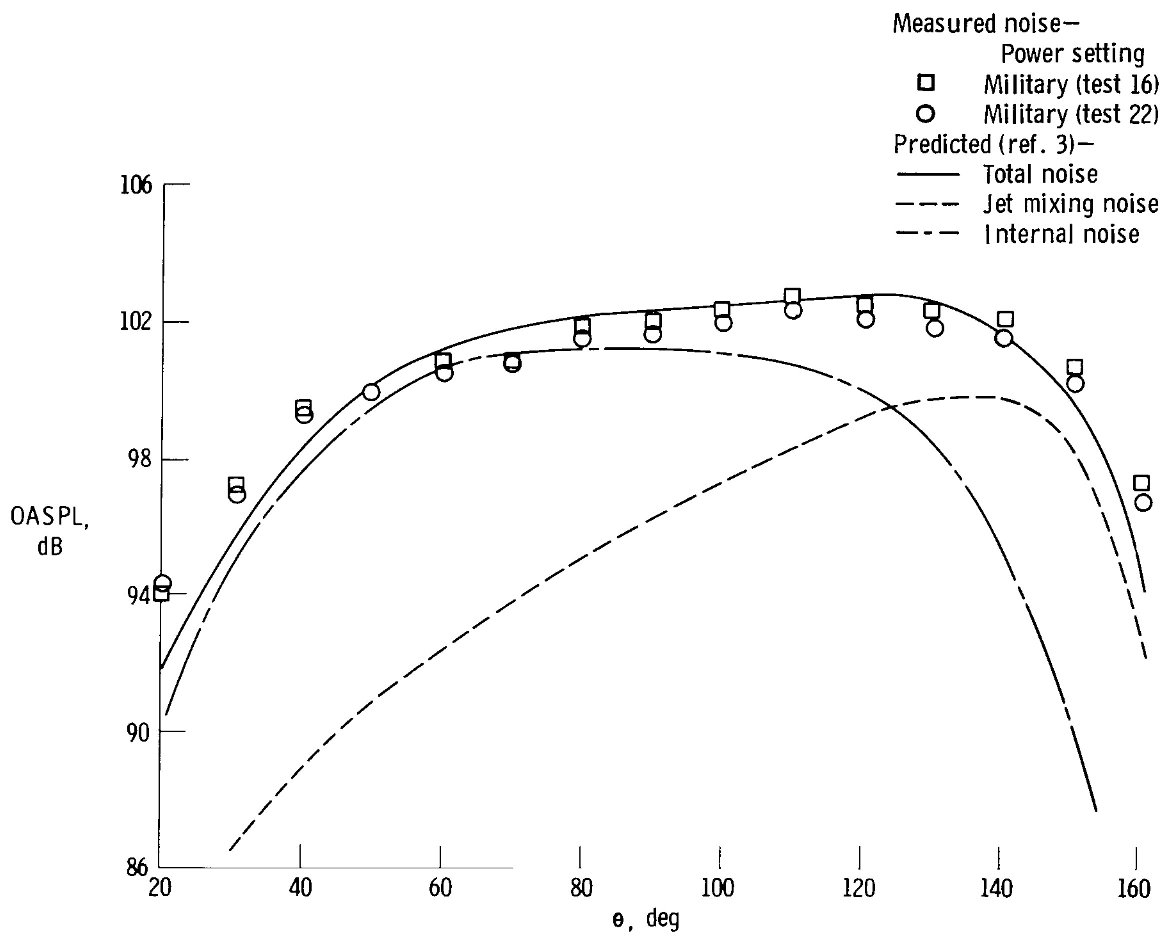
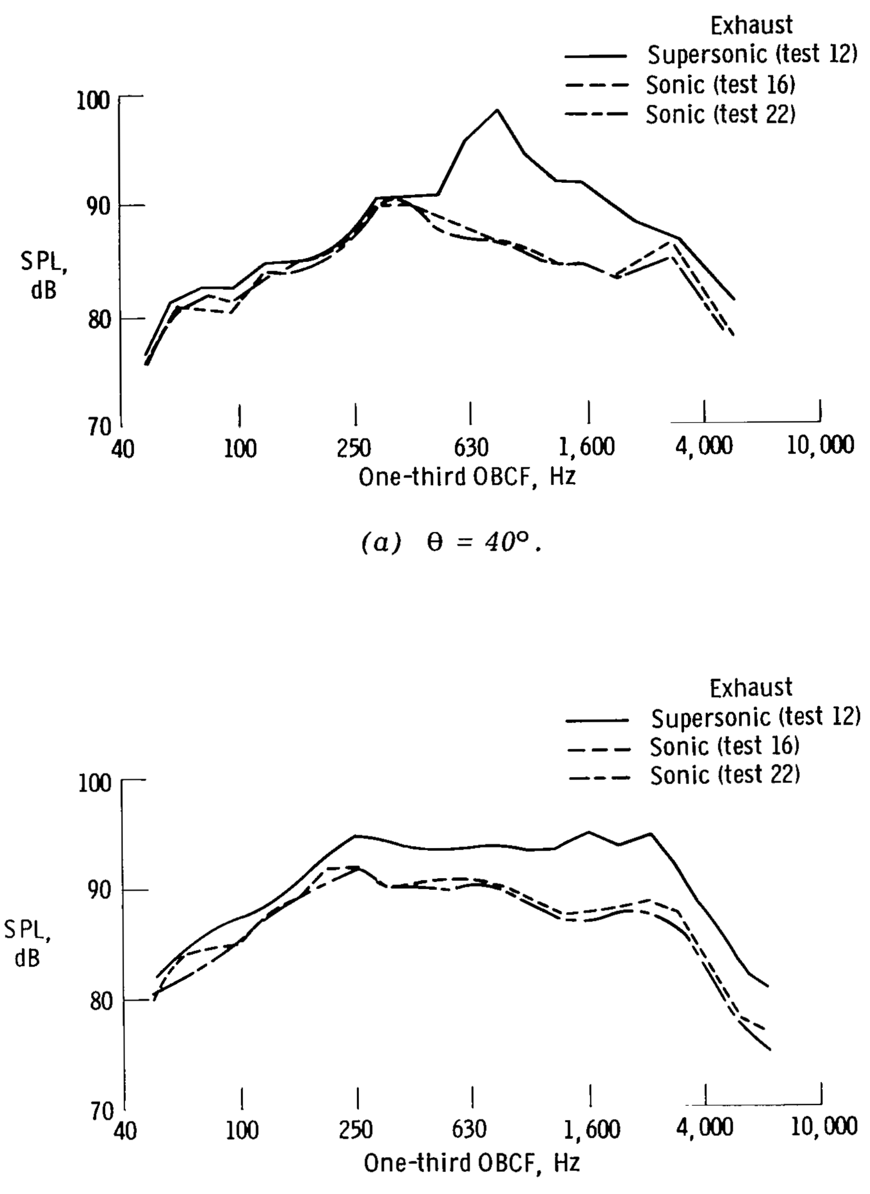


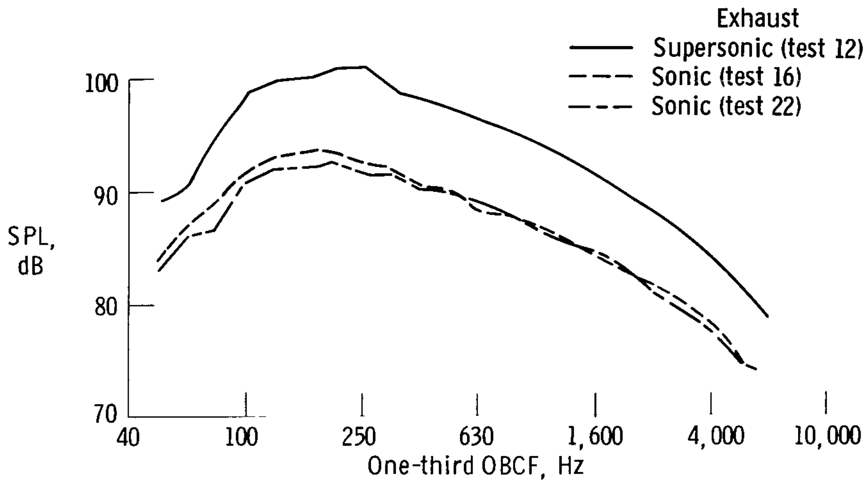
Figure 23. Comparison of measured with predicted flyover noise for military power setting. Sonic exhaust; 152-meter (500-foot) flyover.



(a) $\theta = 40°$.

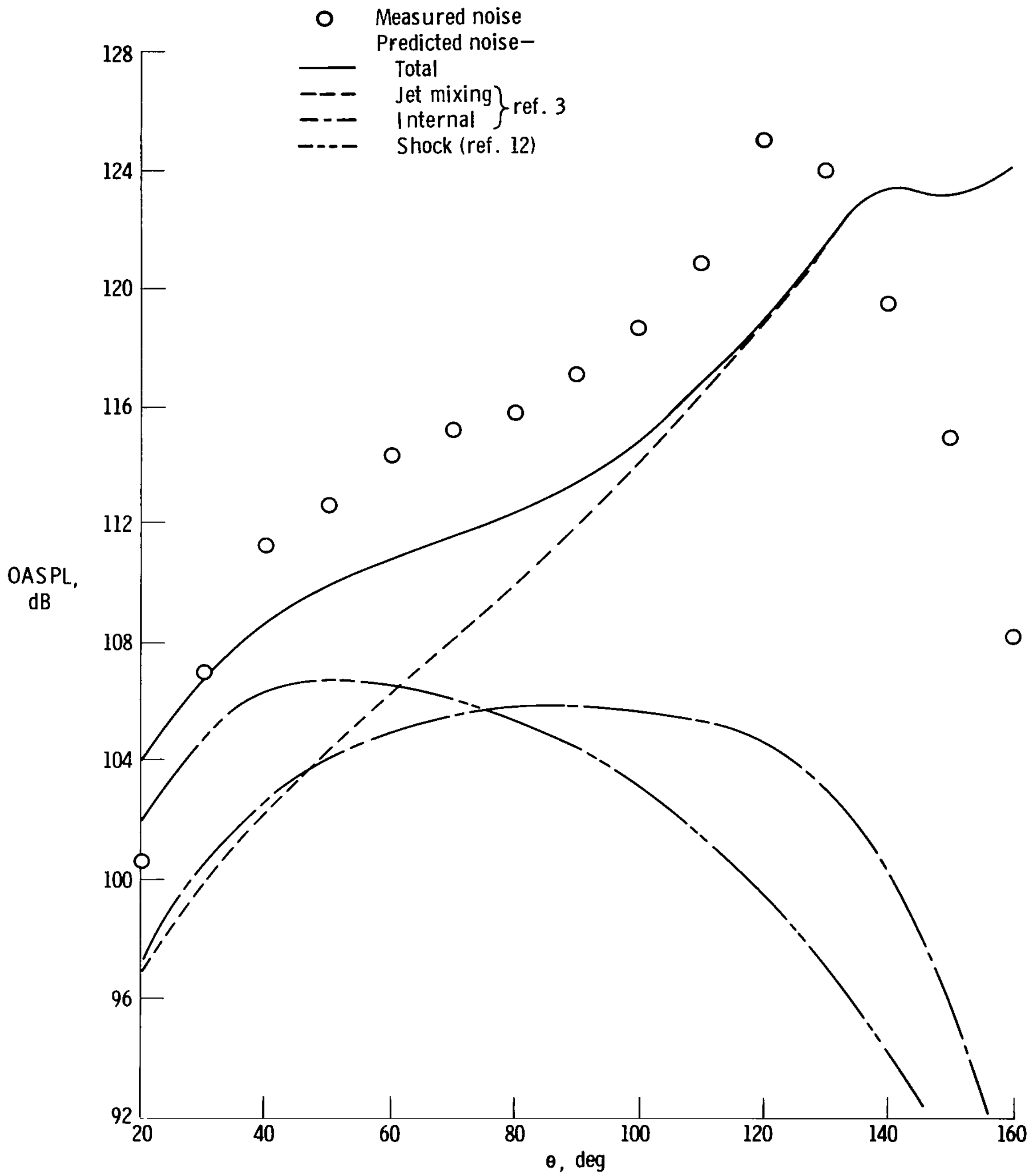
(b) $\theta = 90°$.

Figure 24. Comparison of supersonic with sonic exhaust sound spectra for military power setting. One-hundred-fifty-two-meter (500-foot) flyover.



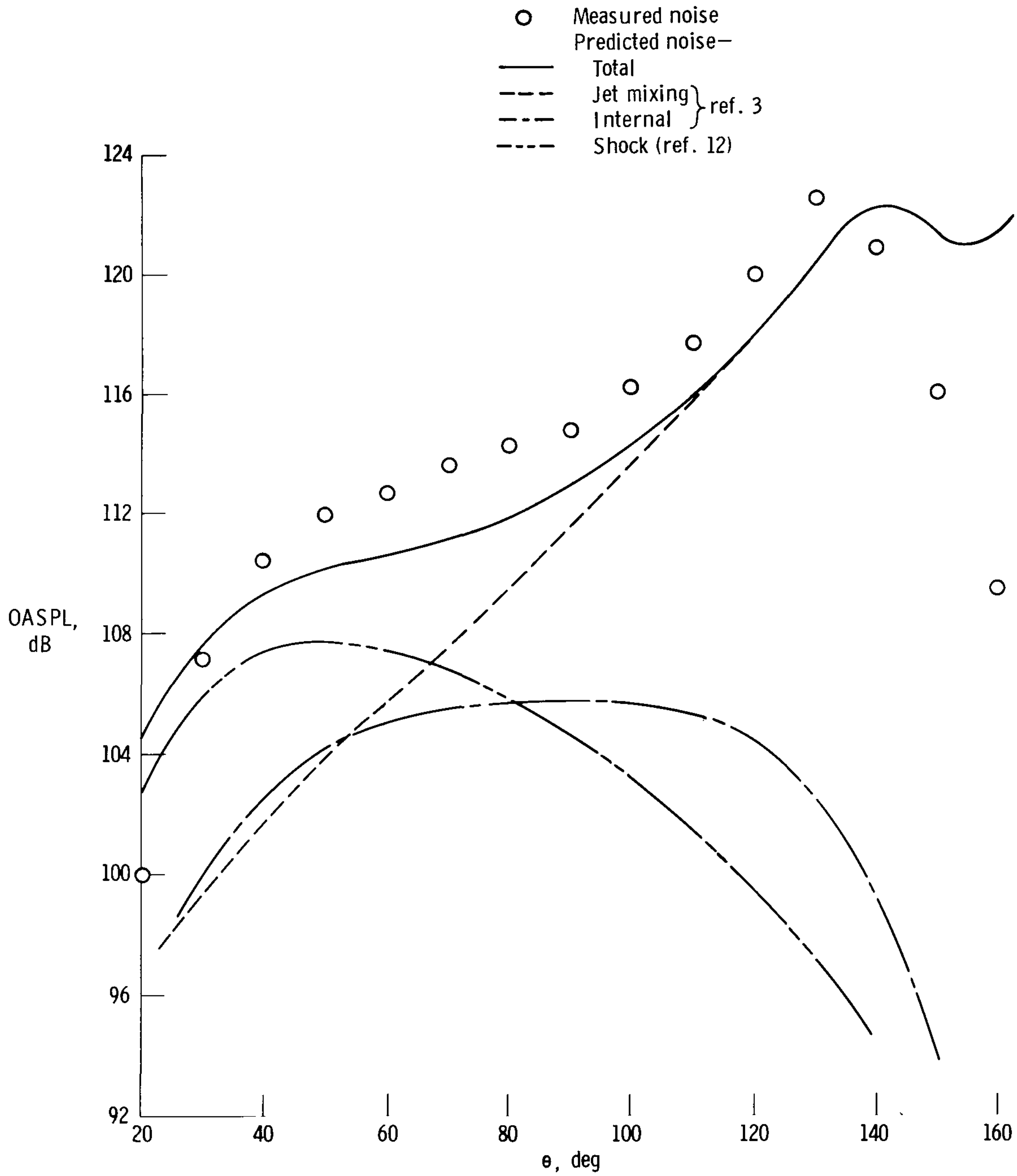
(c) $\theta = 130°$.

Figure 24. Concluded.



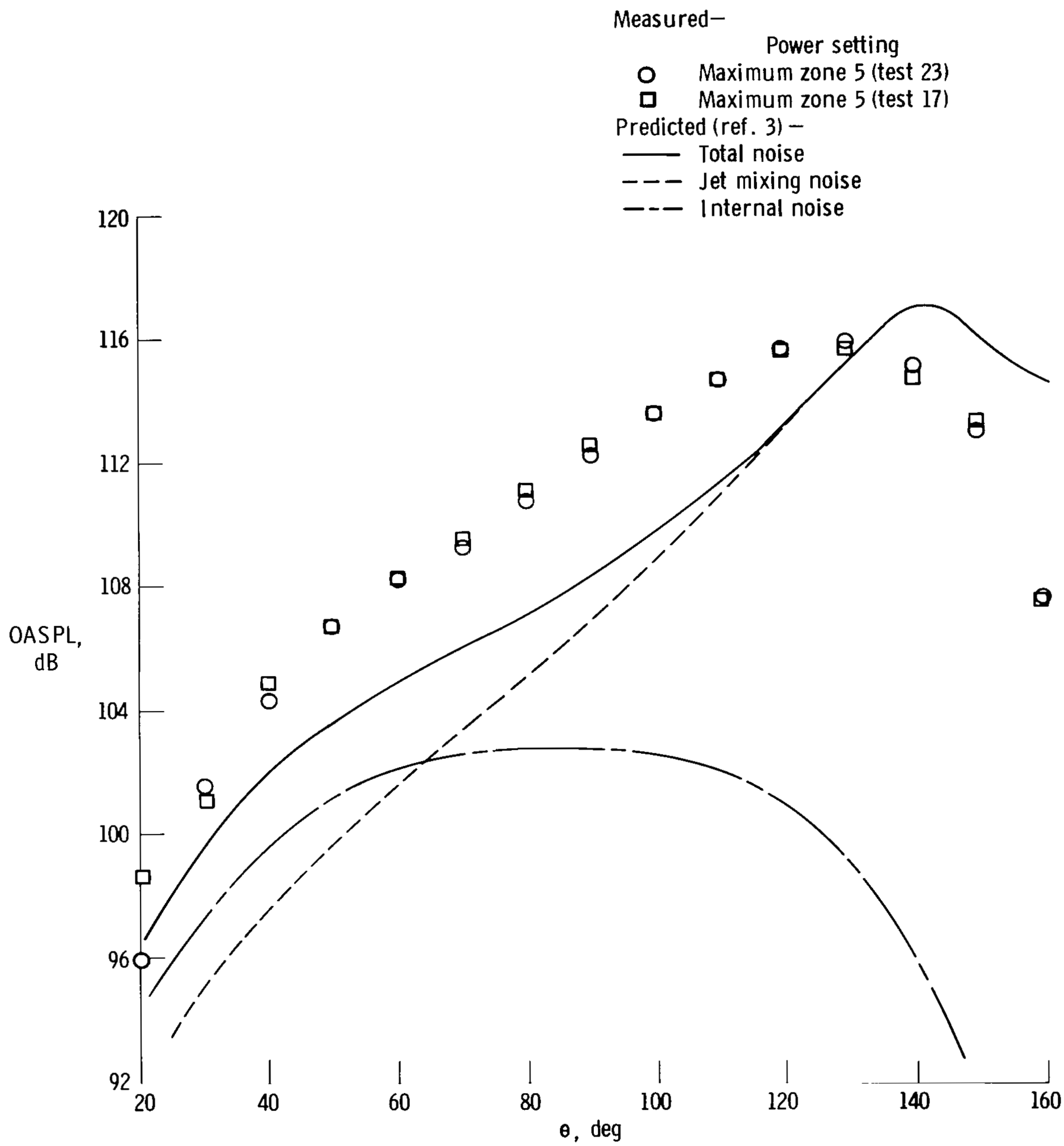
(a) Maximum zone 5 (test 13) power setting.

Figure 25. Comparison of measured with predicted flyover noise. Supersonic exhaust; afterburning power settings; 152-meter (500-foot) flyover.



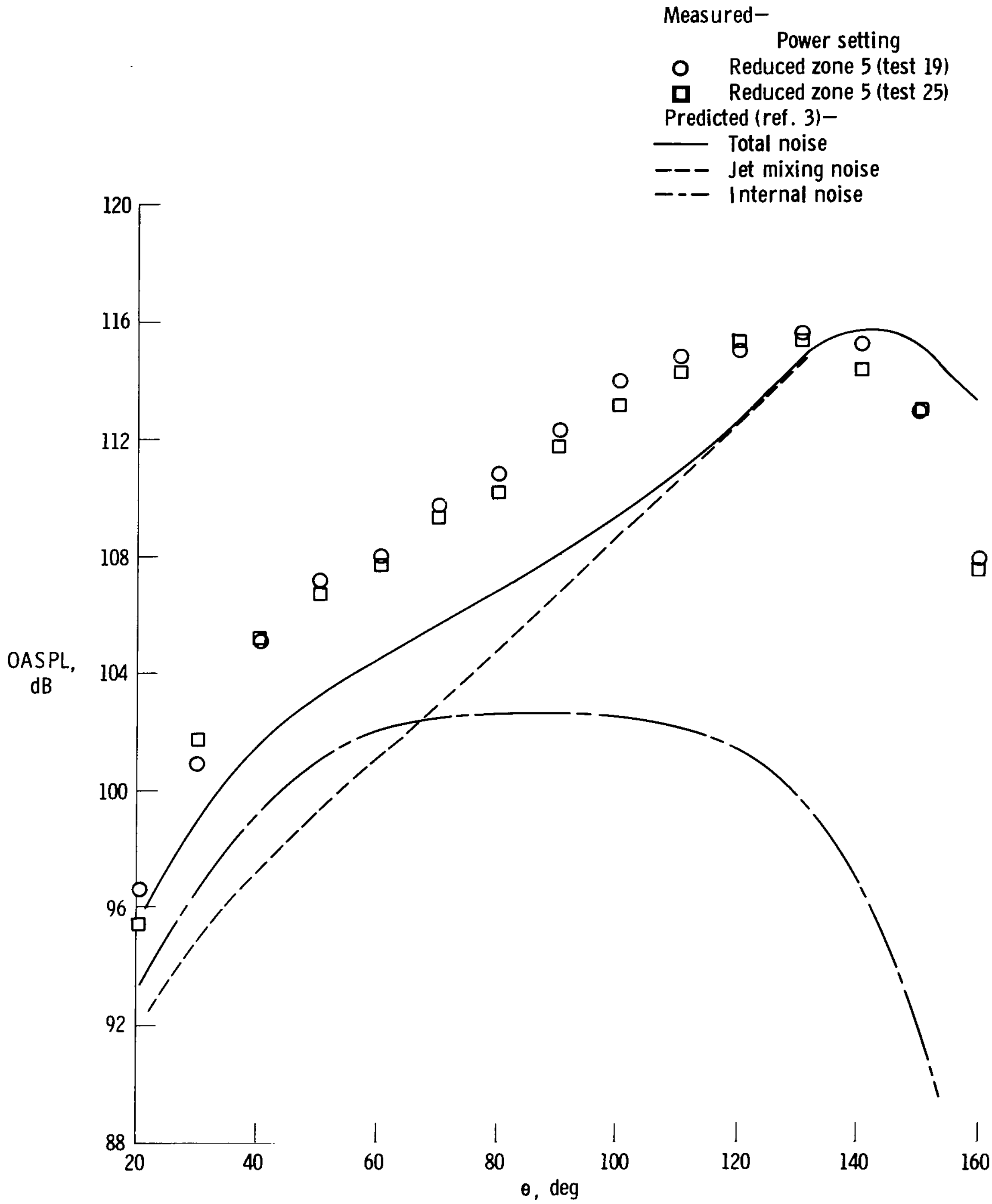
(b) Reduced zone 5 (test 15) power setting.

Figure 25. Concluded.



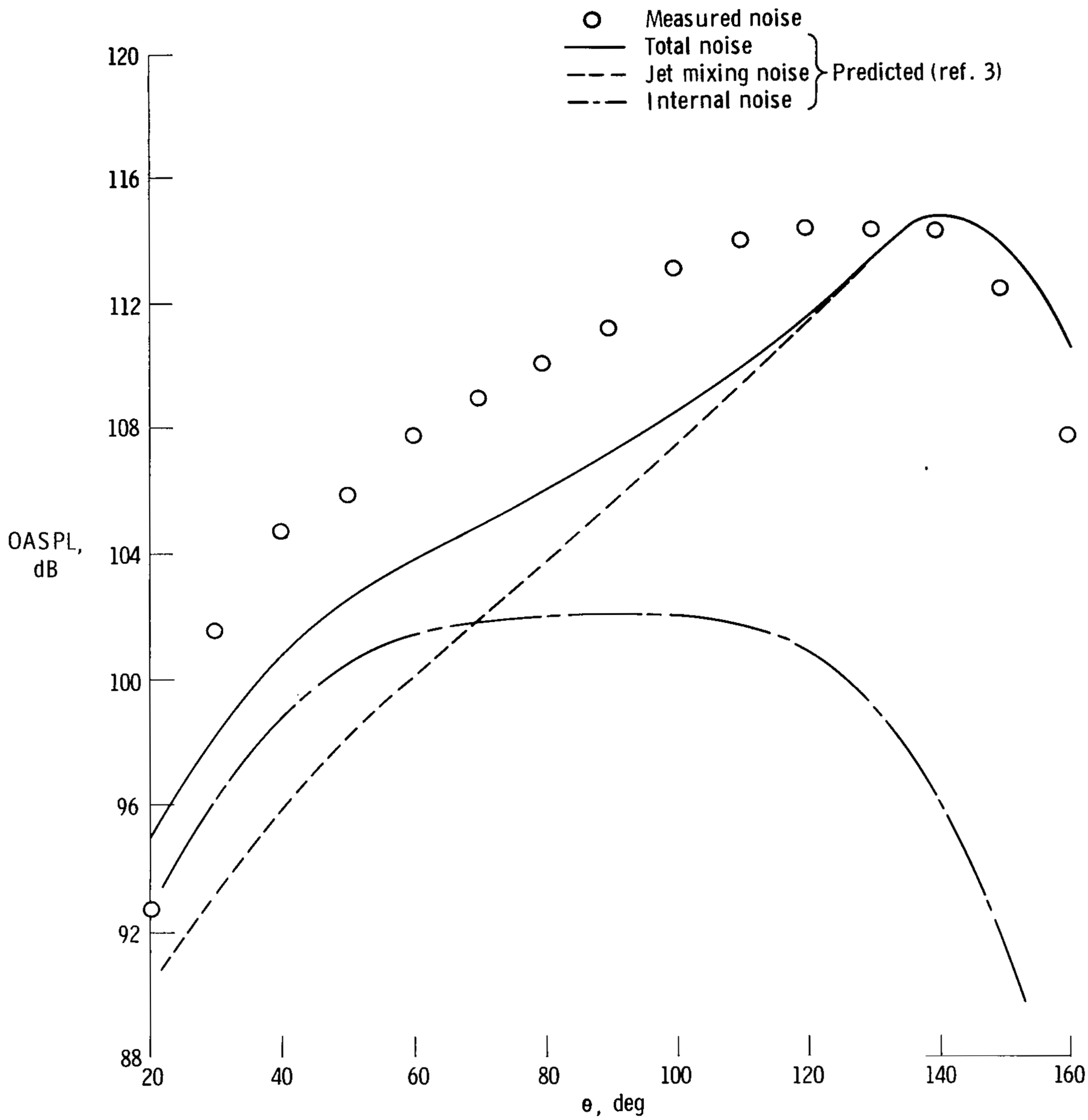
(a) Maximum zone 5 (test 17 and 23) power settings.

Figure 26. Comparison of measured with predicted flyover noise. Sonic exhaust; afterburning power settings; 152-meter (500-foot) flyover.



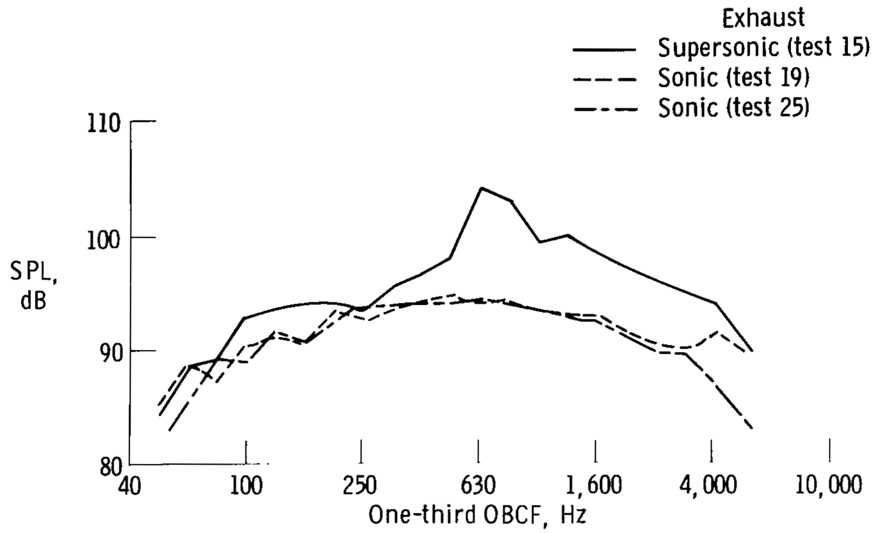
(b) Reduced zone 5 (test 19 and 25) power settings.

Figure 26. Continued.

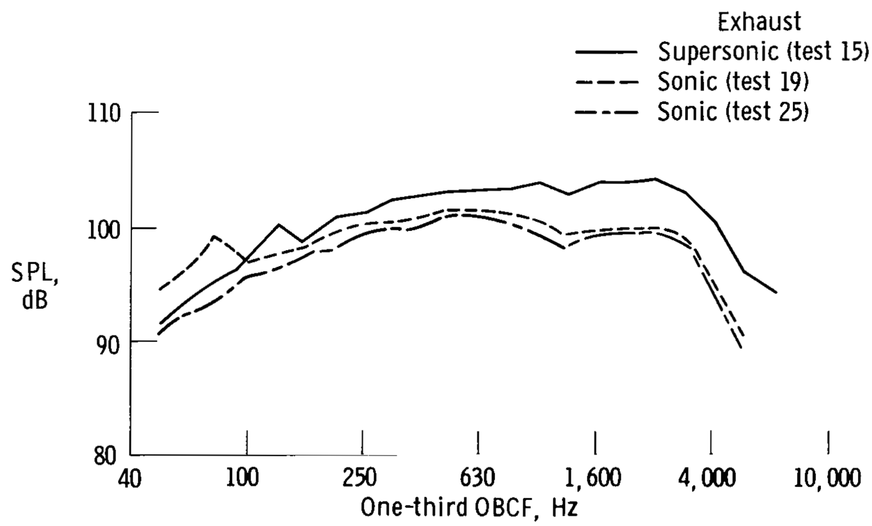


(c) Reduced zone 5 (test 21) power setting.

Figure 26. Concluded.

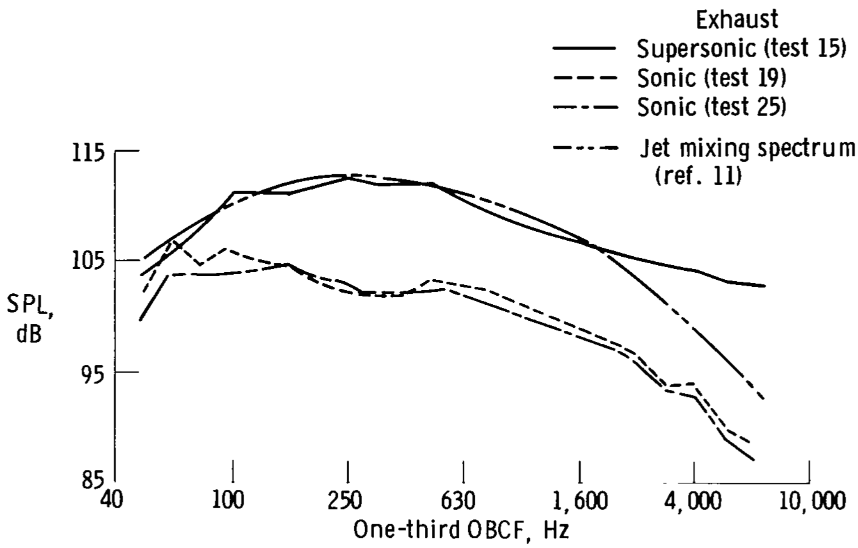


(a) $\theta = 40°$.



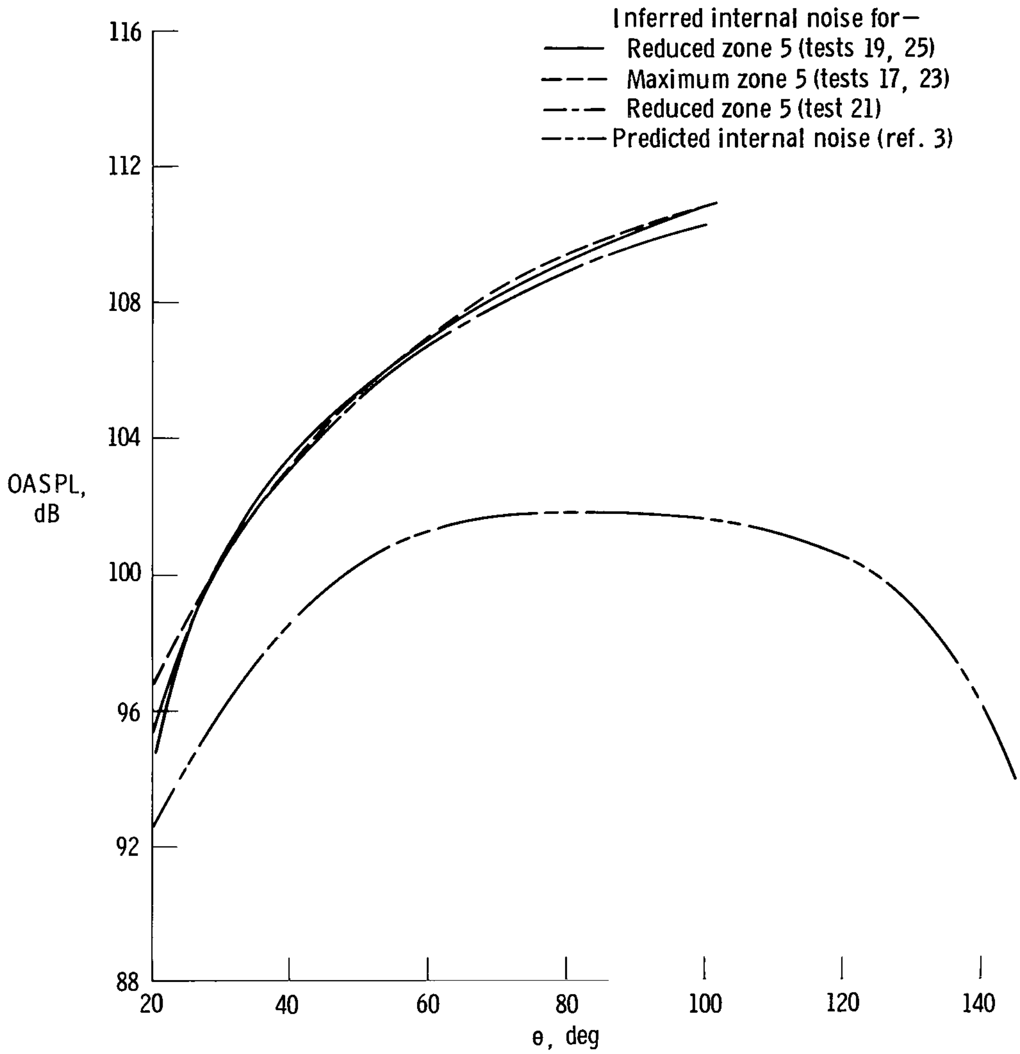
(b) $\theta = 90°$.

Figure 27. Comparison of supersonic with sonic sound spectra for afterburning power settings. One-hundred-fifty-two-meter (500-foot) flyover.



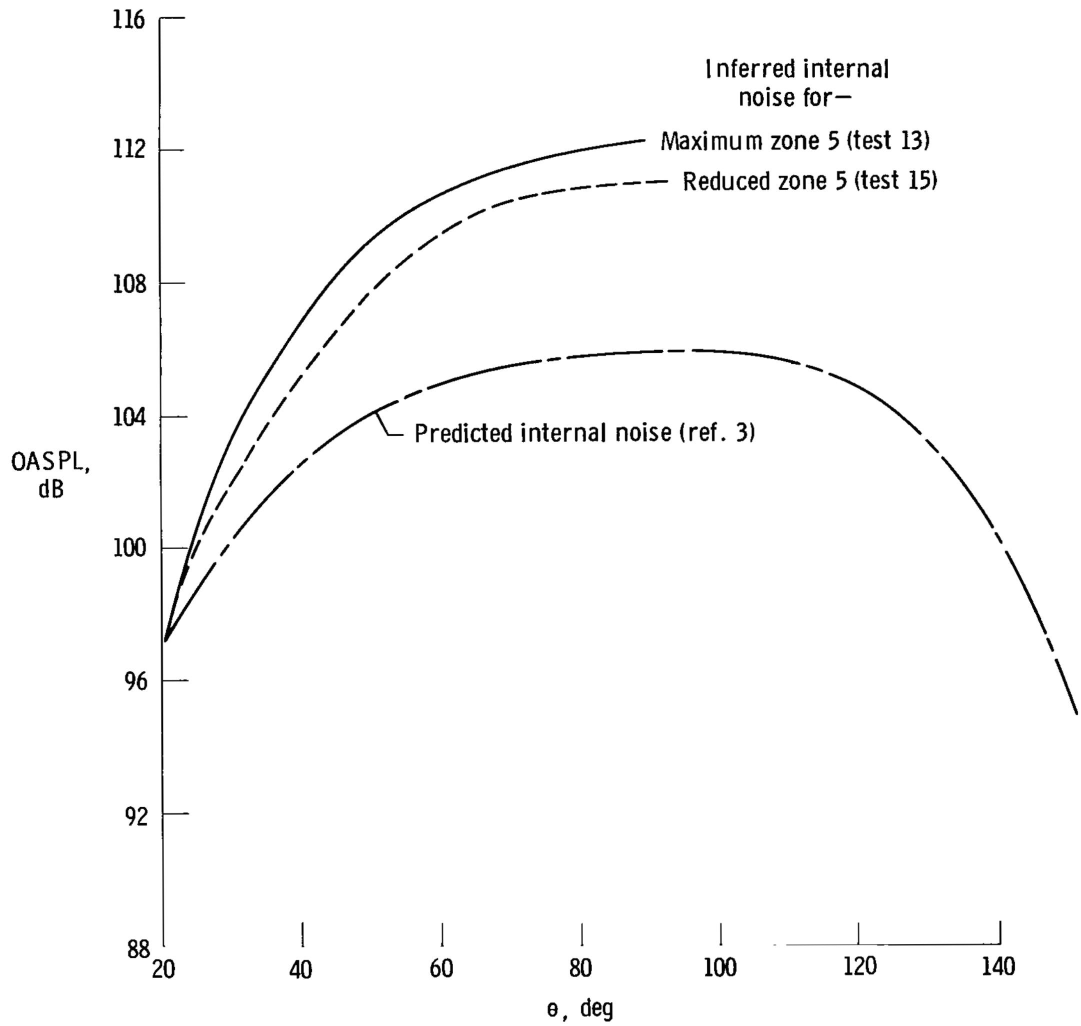
(c) θ = 130°.

Figure 27. Concluded.



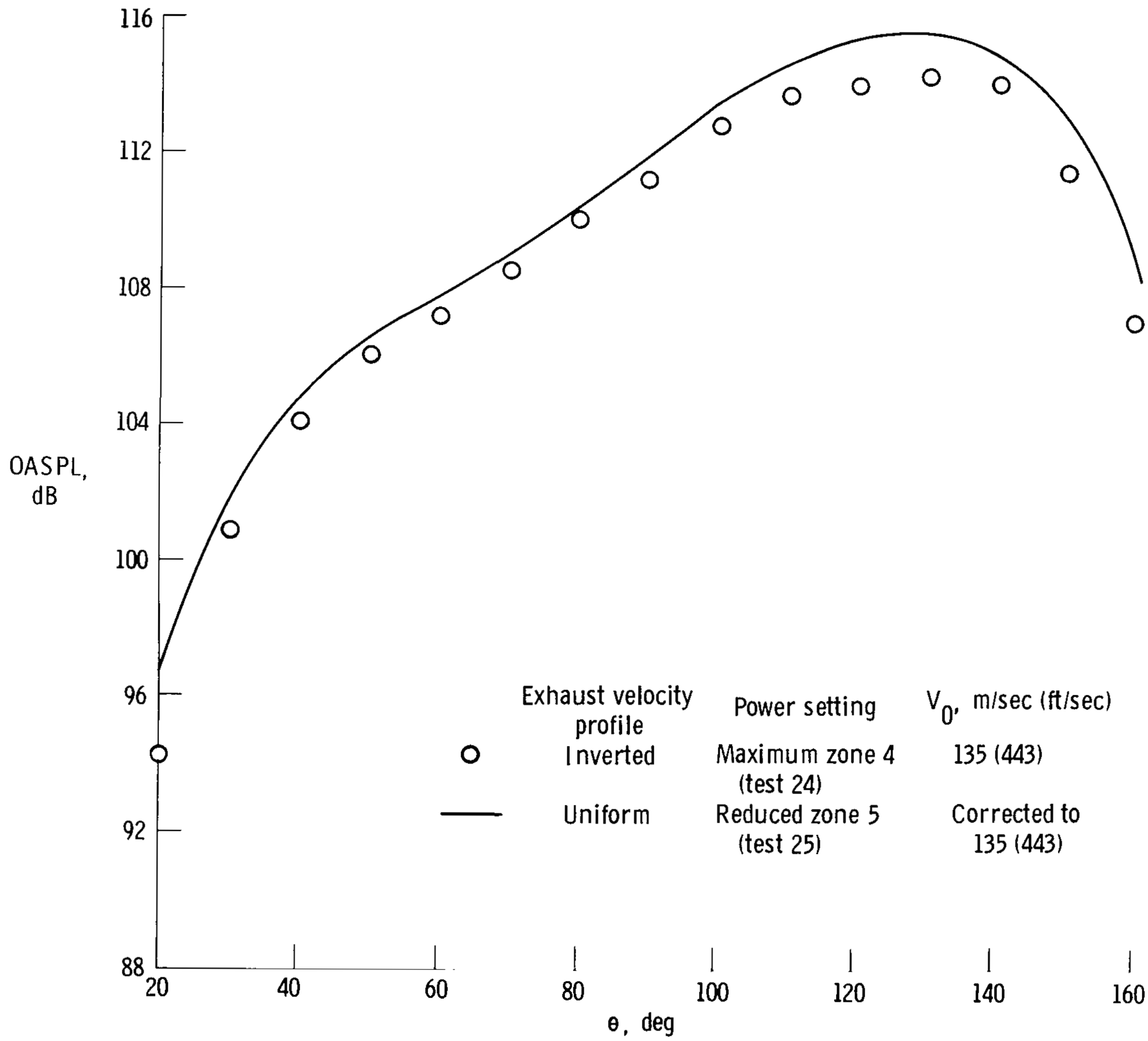
(a) Sonic exhaust.

Figure 28. Comparison of inferred internal noise from afterburning flyovers with predicted internal noise. $M_0 \approx 0.4$.



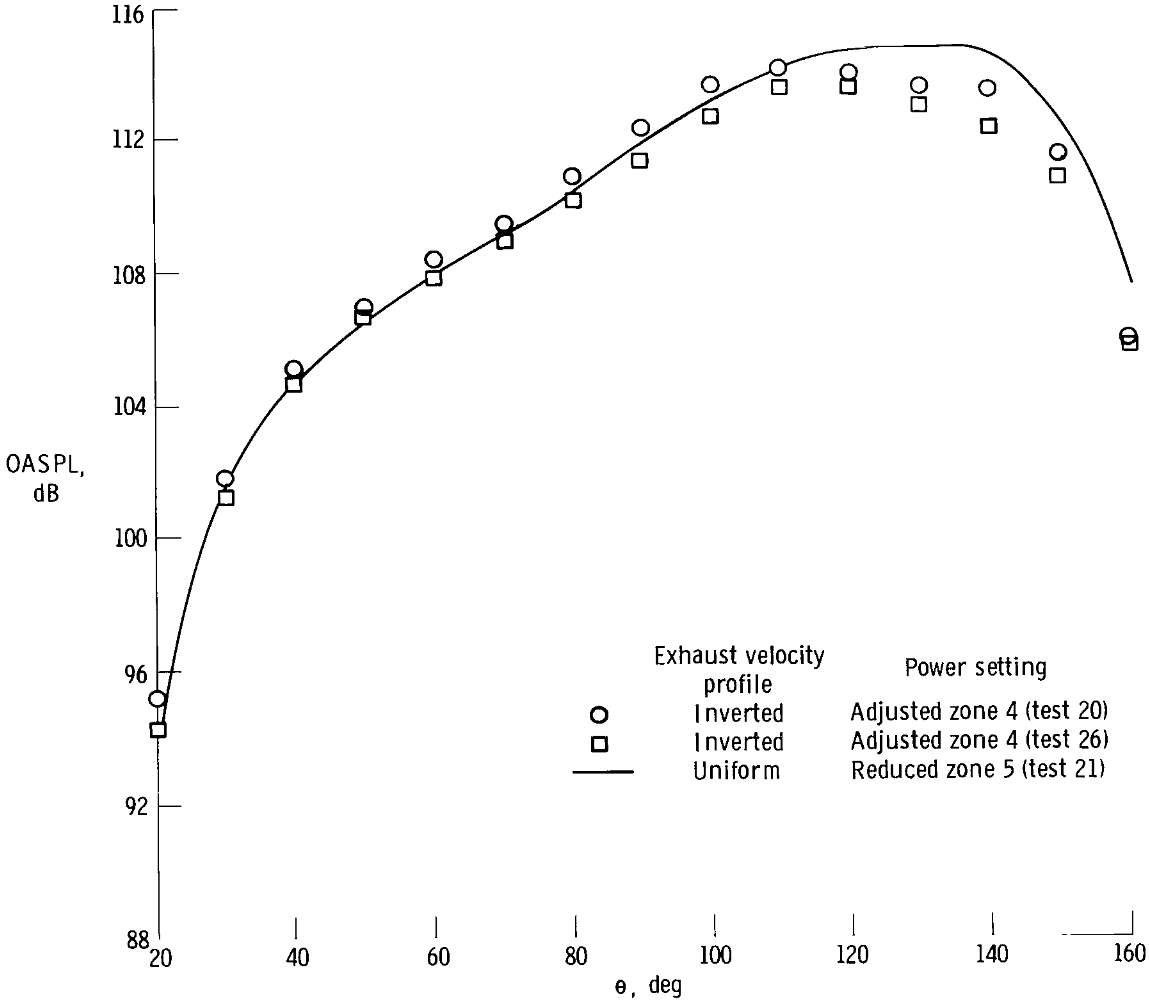
(b) Supersonic exhaust.

Figure 28. Concluded.



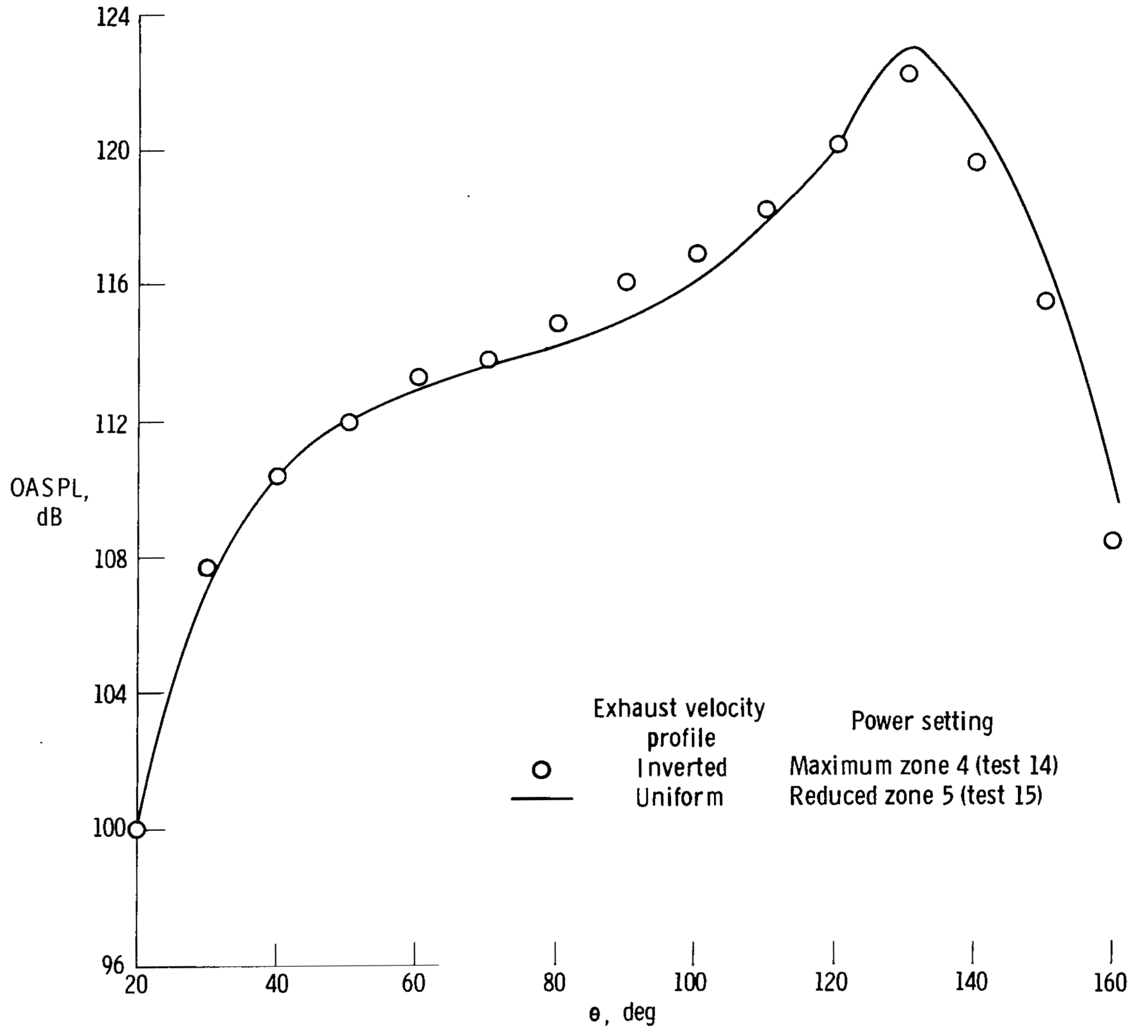
(a) Maximum zone 4 (test 24) and reduced zone 5 (test 25) power settings.

Figure 29. Comparison of inverted with uniform exhaust velocity profile flyover noise. One-hundred-fifty-two meter (500-foot) flyover.



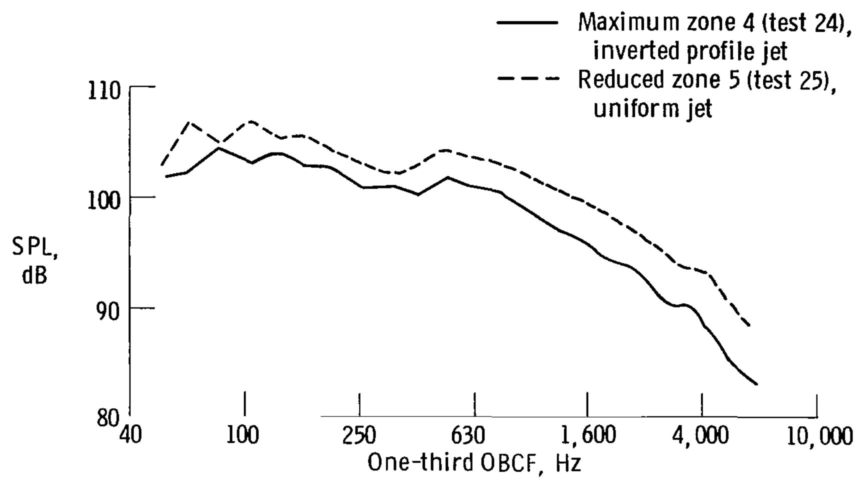
(b) Adjusted zone 4 (test 20 and 26) and reduced zone 5 (test 21) power settings.

Figure 29. Continued.

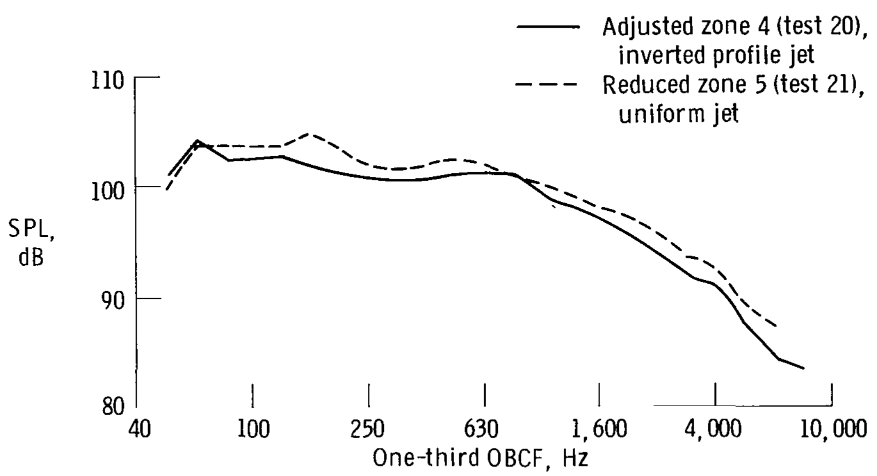


(c) Maximum zone 4 (test 14) and reduced zone 5 (test 15) power settings.

Figure 29. Concluded.

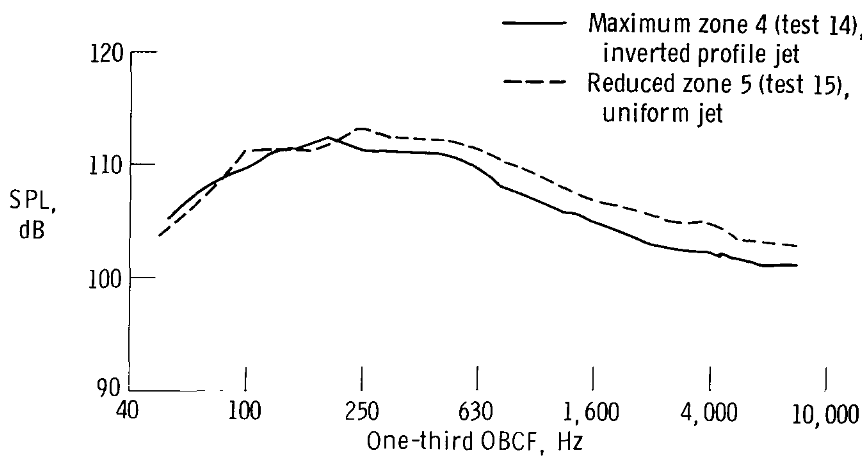


(a) Tests 24 and 25.



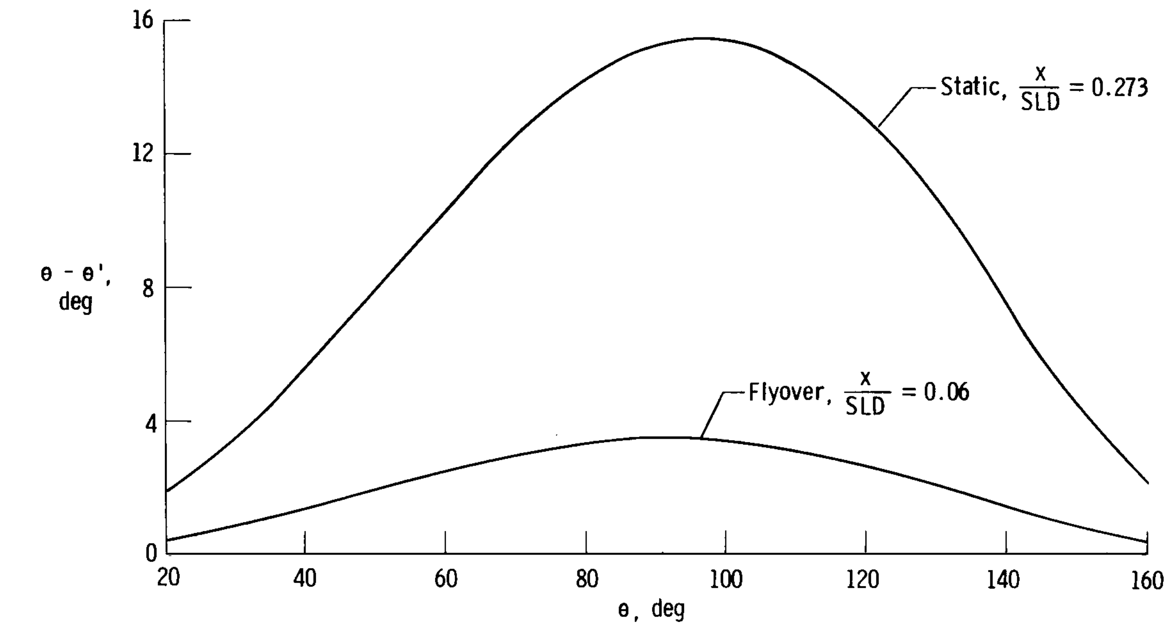
(b) Tests 20 and 21.

Figure 30. Comparison of sound spectra for inverted and uniform exhaust velocity profiles for 152-meter (500-foot) flyover. $\theta = 130°$.

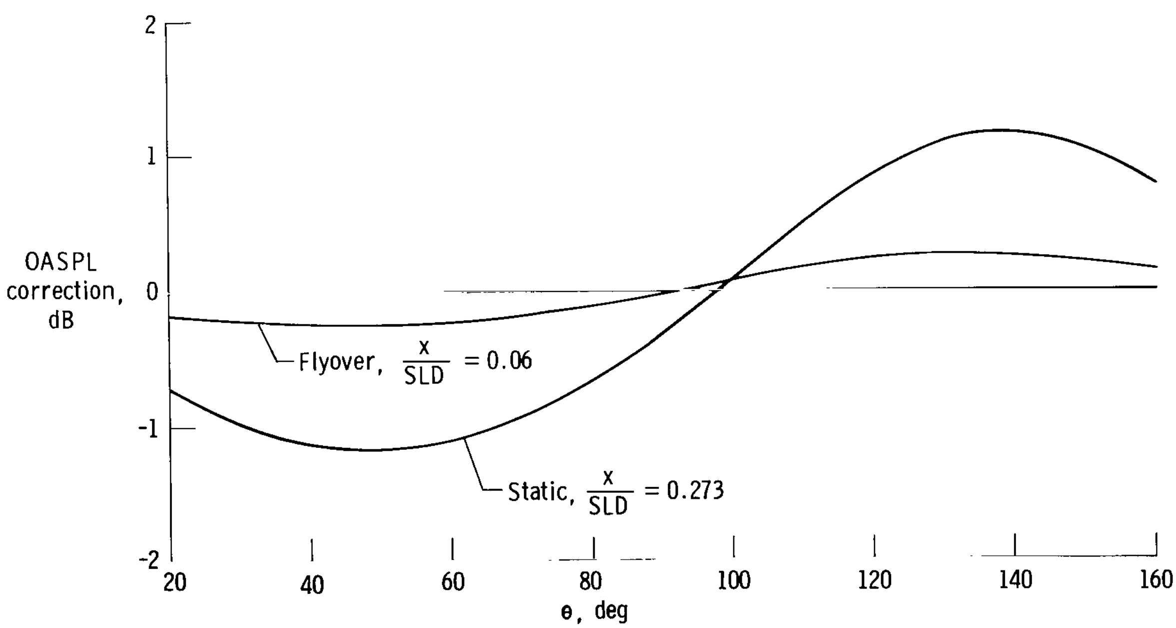


(c) Tests 14 and 15.

Figure 30. Concluded.



(a) Angular correction.



(b) OASPL correction.

Figure 31. Corrections to jet mixing noise prediction for noise source downstream of nozzle exit.

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7. Author(s) Frank W. Burcham, Jr. and Paul L. Lasagna (Dryden Flight Research Center), and Stanley C. Oas (Boeing Commercial Airplane Company)		8. Performing Organization Report No. H-1017
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15. Supplementary Notes		

16. Abstract

The noise of the TF30 afterburning turbofan engine in an F-111 airplane was determined from static (ground) and flyover tests. A survey was made to measure the exhaust temperature and velocity profiles for a range of power settings. Comparisons were made between predicted and measured jet mixing, internal, and shock noise.

It was found that the noise produced at static conditions was dominated by jet mixing noise, and was adequately predicted by current methods. The noise produced during flyovers exhibited large contributions from internally generated noise in the forward arc. For flyovers with the engine at nonafterburning power, the internal noise, shock noise, and jet mixing noise were accurately predicted. During flyovers with afterburning power settings, however, additional internal noise believed to be due to the afterburning process was evident; its level was as much as 8 decibels above the nonafterburning internal noise. No prediction is available for afterburning internal noise. Designs of future afterburning or duct-burning engines should take into consideration the effects of internal noise, which may not be evident from static testing.

Power settings that produced exhausts with inverted velocity profiles appeared to be slightly less noisy than power settings of equal thrust that produced uniform exhaust velocity profiles both in flight and in static testing.

17. Key Words (Suggested by Author(s))		18. Distribution Statement	
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